## 演讲嘉宾介绍

A Trivedi 教授目前担任印度德里技术大学土木工程学院院长，同时为印度结构工程师协会成员、美国土木工程师学会成员、印度岩石力学与隧道技术学会成员、 ISTE 成员、IGS 成员等。目前是著名期刊 Acta Geotechnica、International Journal of Geosynthetics 和 Ground Engineering, Springer 的编委会成员，并且是国际一些知名期刊的审稿人。主要研究方向为岩石力学、土体动力学、生物土壤和深基础等。主持并参与过印度众多大型项目，在国际知名期刊上发表论文 75 篇，并拥有专利 8 项，指导 50 余位硕士生、博士生。



# Development and Application of Deep (Pile) Foundation In India
# 印度深（桩）基础的发展和应用

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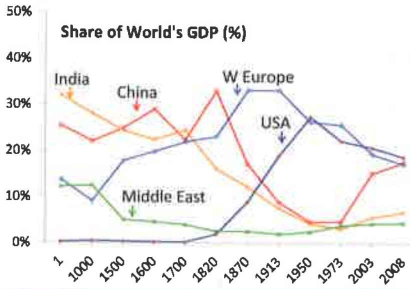
## Timeline of World GDP & Civil Construction Activities
## 世界GDP时间轴&土建施工活动

不同时期的土建量与GDP成正比.

Civil Engineering works in different millenniums had been proportional to GDP.




## Deep Foundation In Ancient India
## 古代印度的深基础

- The origin of well foundations credits back to historic Indian engineering activities past two millinium.
- 沉井基础的起源可以追溯到印度过去两千年的工程中.
- The use of well foundations in India hits back to two millennums for providing deep foundation beneath the water level for monuments, bridges and aqueducts.
- 在印度，沉井基础的使用可以追溯到2000年前，作为一些历史遗迹、桥梁和渡槽水位以下的深基础.
- Well foundation in South Indian Temples and North India Monuments (Taj Mahal and Red Fort)
- 印度南部的寺庙和印度北部的历史遗迹(泰姬陵和红堡)均使用沉井基础的

## Deep Foundations In Last Millennium
## 深基础过去一千年的发展概况

India and China being one of the affluent countries in last millennium had very large number of

过去一千年，印度和中国作为地大物博的国家，拥有拥有大量的：

- Temples 寺庙
- Castles 城堡
- Forts要塞
- Reservoirs水库
- Deep well foundation深井式基础

## Pile Foundations In Last Century
## 上世纪的桩基

- Bored cast-in situ piles and driven cast-in situ piles were used
- 开始使用钻孔灌注桩和现浇桩
- Precast piling technology was picking up- very few projects
- 预制桩技术的应用正在兴起——但项目很少
- Spliced pile technology not in use 拼接桩技术未开始使用
- Designs followed by the code of practice based on past experiences with conservative parameters
- 桩基设计所参照的规范是基于工程经验，参数选用保守
- The field test results have shown much higher load capacity compared to the theoretical estimated capacity
- 现场试验结果得出的承载力比理论估计的承载力高得多
- Instrumental field test were rare which due to high cost of imported instruments
- 由于进口仪器的高成本，现场测试很少见

## Pile Foundation In Current Scenario
## 目前的桩基

- Bored Piles 钻孔桩
- Driven Cast-In Situ Piles 锤击沉管灌注桩
- Precast Piles预制桩

- Clients belief that the instrumental test is more an academic exercise and does not benefit the project.
- 业主认为，仪器测试更像是一项学术活动，并不会使项目受益。
- As far as construction technology is concerned, most of the bored piles, even for major projects were installed by a conventional tripod with a chisel and a bailer or with direct circulation (DCM) method.
- 考虑到建造技术，大多数项目甚至重大项目的钻孔桩都是由传统的三脚架用凿子、捞砂筒或DCM方法安装的。
- The conventional method using a tripod is very slow and less effective.
- 使用三脚架的传统方法非常慢并且效率较低。

## Foundation Practices
## 有关基础的实践

- Largely Conservative过于保守
- Slow 缓慢
- Labour Intensive Methods and Equipment劳动密集型的方法和设备

**Reasons原因**

- Construction companies, clients, and consultants do not focus on foundation technologies. 建筑公司、业主和顾问并不关注基础技术。
- Cost of Foundations- 1 to 10% of the civil construction cost of a project.
- 基础的成本占土木工程建设成本的1%到10%。
- Special Cases- Marine structures and bridges- 50% of the cost of the constructed facility. 特殊情况——海洋结构和桥梁——占建造设施的一半成本。

## Choice of Pile type
## 桩型选择

- Strata conditions 地层条件
- Availability of equipment's设备的可用性
- Method followed for construction施工方法
- Loading requirements荷载要求

**Sri Ranganathaswamy Temple**

Height-73.02 m, 1987 C.E, Srirangam , Tamil Nadu
Deep Foundation

**Murdeshwara Temple**

Height-72.40 m, 2008 C.E, Murdeshwara, Karnataka, India
Deep Foundation

**Annamalaiyar Temple**

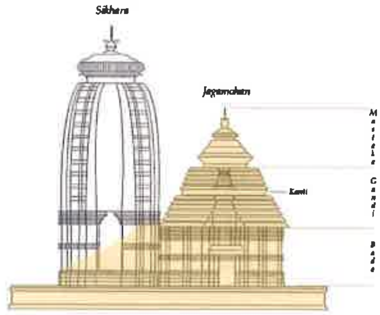
Height-66.0 m, 9th Century C.E, Tiruvannamalai, Tamil Nadu, India
Deep Foundation

**Srivilliputhur Andal Temple**

Height-59.0 m, C.E, Srivilliputhur, Tamil Nadu, India
Deep Well Foundation

**Konark Sun Temple**

Height-59.0 m, C.E, Srivilliputhur, Tamil Nadu, India
Deep Well Foundation




**Depth of Foundation in a Golden Ratio**
**基础深度按黄金比例设计**

## Difficulties In Pile Installation Precast Driven Piles 预制桩的安装难点

- Difficulty in handling a larger pile cross section & length
- 处理较大截面和长度的桩时较困难
- Inadequate space to establish a casting yard
- 没有足够的空间来建造一个预制场
- Difficulty in prediction of pile length due to strata variations, resulting in extra pile length
- 由于地层的变化而导致桩长预测困难，导致需增加桩长
- Difficulty in cutting of extra pile length if hard stratum is at higher level

如果硬地层在更深处，切桩比较困难

Difficulty to drive with a follower section made up of steel and later grown with in situ concrete

- 难以打入由钢和混凝土组成的构件



## Difficulties In Pile Installation Driven Cast-In Situ Piles 钻孔灌注桩的安装难点

- Limitations on size (500-600 mm)尺寸限制 (500-600 mm)
- Limitation on length (35-35 m) even with a jointed casing pile
- 即使对于连接套管桩， 桩长限制 也是(35-35 m)
- Water tightness of the joint 接头水密性
- Uplifting of the casing pile due to buoyancy before the steel cage is lowered 在下沉钢笼之前，在浮力作用下套管抬升
- Difficulties in concreting of pile and withdrawing of the casing so that outside ground water/s do not force into the soil
- 浇筑混凝土和取出套管时，很难使外部地下水不进入土壤



## Difficulties In Pile Installation Cast in Situ Piles 灌注桩的安装难点

- Collapsing of soil during the concreting operation is a common problem, in spite of bore hole stabilization with bentonite slurry, loose cohesion less saturated soil
- 混凝土施工过程中土壤的塌陷是一个常见的问题，尽管膨润土泥浆、低粘聚力和低饱和度的土可以保持钻孔的稳定。
- Limitation of temporary liner to a depth of 2-5 m
- 临时衬管的限制深度为2-5米。
- Very high cost of permanent steel liners for large depth
- 高深度的永久性钢衬套成本非常高；
- Limitation of cleaning bottom of the bore hole before concreting, results in soft toe and reduces pile capacity
- 在浇筑混凝土前，钻孔的底部清空可能不彻底，会导致桩承载力降低。
- Use of heavy hammer to remove of this extra concrete can damage the pile concrete below the cut off.
- 用重锤去除多余的混凝土会损坏桩身混凝土。



## Pile Design Issues Vertical & Horizontal Loads 竖向与水平载荷作用下桩的设计问题

- Pile designed methods are well established.桩的设计方法已经很完善。
- Selection of key parameters namely earth pressure coefficients, adhesion factor are conservative.关键参数的选择即土压力系数，粘着系数都很保守。
- Cost of project considered prohibitive for detailed investigation.
- 工程造价无法进行精细的调查。
- p-y, q-s and t-z plots are rarely used.很少使用p-y, q-s 和 t-z 曲线图。
- Pile groups are designed based upon single pile capacity using 2D (if on rocks)or 3D (soils) spacing.
- 群桩的设计基于单桩承载力，桩间距采用2D（适用于岩层）或3D（适用于土层）

## Pile Design Issues
## Vertical Compression & Horizontal Loads
## 竖向压力与水平载荷作用下桩的设计问题

- Advantage of group efficiency is not utilized. 群桩效应的优势没有被利用。
- Reduction due to interaction under horizontal loads is not adequately considered. 没有充分考虑水平荷载下桩间相互作用导致的折减。
- The consideration for the negative skin friction is not adequately addressed.
- 表面负摩阻的问题没有得到充分解决。
- Pile load test are considered as academic exercise.
- 桩载荷试验被认为是学术实践。

## Load Carrying Capacity-Static Formula
## 承载能力-静态公式
## IS: 2911 (Part I/ Sec 1) - 1979

**A-1. PILES IN GRANULAR SOILS**

A-1.1 The ultimate bearing capacity ( $Q_u$ ) of piles in granular soils is given by the following formula:

$$Q_u = A_p \left( \tfrac{1}{2} D \gamma N_\gamma + P_D N_q \right) + \sum_{i=1}^{n} K P_{Di} \tan \delta A_{si}$$

where

$A_p$ = cross-sectional area of pile toe in cm²;
$D$ = stem diameter in cm;
$\gamma$ = effective unit weight of soil at pile toe in kg/cm³;
$P_D$ = effective overburden pressure at pile toe in kgf/cm²;
$N_\gamma$ and $N_q$ = bearing capacity factors depending upon the angle of internal friction $\phi$ at toe;
$\sum_{i=1}^{n}$ = summation for $n$ layers in which pile is installed;
$K$ = coefficient of earth pressure;
$P_{Di}$ = effective overburden pressure in kgf/cm² for the $i^{th}$ layer where $i$ varies from 1 to $n$;
$\delta$ = angle of wall friction between pile and soil, in degrees (may be taken equal to $\phi$); and
$A_{si}$ = surface area of pile stem in cm² in the $i^{th}$ layer where $i$ varies from 1 to $n$.

NOTE 1 — $N_\gamma$ factor can be taken for general shear failure according to IS : 6403-1971*.

NOTE 2 — $N_q$ factor will depend, apart from nature of soil, on the type of pile and its method of construction, and the values are given in Fig. 1 which are based on recommendation of Vesic.

NOTE 3 — The earth pressure coefficient $K$ depends on the nature of soil strata, type of pile and its method of construction. In loose to medium sands, $K$ values of 1 to 3 should be used.

NOTE 4 — The angle of wall friction may be taken equal to angle of shear resistance of soil.

NOTE 5 — In working out pile capacities using static formula for piles longer than 15 to 20 times the pile diameter, maximum effective overburden at the pile tip should correspond to pile length equal to 15 to 20 times of the diameter.

## Bearing Capacity Factors For Driven Piles
## 钻孔桩的承载系数
## IS: 2911 (Part I/ Sec 1) - 1979

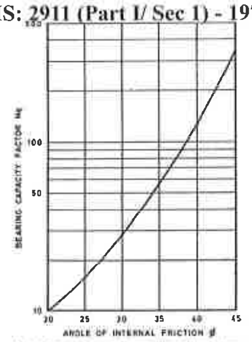



FIG. 1 Bearing Capacity Factor $N_q$ for Driven Piles

## Load Carrying Capacity-Static Formula
## 承载能力-静态公式
## IS: 2911 (Part I/ Sec 1) - 1979

**A-2. PILES IN COHESIVE SOILS**

A-2.1 The ultimate bearing capacity of piles ( $Q_u$ ) in cohesive soil is given by the following:

$$Q_u = A_p . N_c . C_p + \alpha . \bar{C} . A_s$$

where

$A_p$ = cross-sectional area of pile toe in cm²,
$N_c$ = bearing capacity factor usually taken as 9,
$C_p$ = average cohesion at pile tip in kgf/cm²,
$\alpha$ = reduction factor,
$\bar{C}$ = average cohesion throughout the length of pile in kgf/cm², and
$A_s$ = surface area of pile shaft in cm².

NOTE 1 — The following values of $\alpha$ may be taken depending upon the consistency of the soils:

| *Consistency* | *N Value* | *Value of α* |
|---|---|---|
| Soft to very soft | <4 | 1 |
| Medium | 4 to 8 | 0·7 |
| Stiff | 8 to 15 | 0·4 |
| Stiff to hard | >15 | 0·3 |

NOTE 2 — Static formula may be used as a guide only for bearing capacity estimates. Better reliance may be put on load test of piles.

NOTE 3 — For working out safe load a minimum factor of safety 2·5 should be used on the ultimate bearing capacity estimated by static formulae.

NOTE 4 — $\alpha$ may be taken to vary from 0·5 to 0·3, depending upon the consistency of the soil. Higher values of up to 1 may be used for softer soils, provided the soil is not sensitive.

## Load Carrying Capacity-Static Formula
## 承载能力-静态公式
## IS: 2911 (Part I/ Sec 1) - 1979

**A-3. PILES IN NON-COHESIVE SOILS**

**A-3.1** When full static penetration data are available for the entire depth, the following correlations may be used as a guide for the determination of shaft resistance of a pile.

| *Type of Soil* | *Local Side Friction* $f_s$ |
|---|---|
| Clays and peats where $q_c < 10$ | $\frac{q_c}{30} < f_s < \frac{q_c}{10}$ |
| Clays | $\frac{q_c}{25} < f_s < \frac{q_c}{25}$ |
| Silty clays and silty sands | $\frac{q_c}{100} < f_s < \frac{q_c}{25}$ |
| Sands | $\frac{q_c}{100} < f_s < \frac{q_c}{100}$ |
| Coarse sands and gravels | $f_s < \frac{q_c}{150}$ |

where

$q_c$ = static point resistance, and

$f_s$ = local side friction.

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For non-homogeneous soils the ultimate point bearing capacity may be calculated using the following relationships:

$$q_u = \frac{\frac{q_{c0} + q_{c1}}{2} + q_{c2}}{2}$$

where

$q_u$ = ultimate point bearing capacity,

$q_{c0}$ = average static cone resistance over a depth of 2 $d$ below the base level of the pile,

$q_{c1}$ = minimum static cone resistance over the same 2 $d$ below the pile tip,

$q_{c2}$ = average of the minimum cone resistance values in the diagram over a height of 8 $d$ above the base level of the pile, and

$d$ = diameter of the pile base or the equivalent diameter for a non-circular cross section.

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## Correlation Between SPT Value N and SCPT Point Resistance Qc for Shaft Resistance and Skin Friction of Piles
## 计算桩的桩身摩阻力的标准贯入试验中N值和标准圆锥贯入试验锥尖抗力Qc之间的关系
## IS: 2911 (Part I/ Sec 1) - 1979

| *Soil Type* | $q_c$/N |
|---|---|
| Clays | 2·0 |
| Silts, sandy silts and slightly cohesive silt sand mixtures | 2·00 |
| Clean fine to medium sands and slightly silty sands | 3-4 |
| Coarse sands and sands with little gravel | 5-6 |
| Sandy gravels and gravel | 8-10 |

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## Practices for Dynamic Pile Formula
## 桩动荷载作用下的公式
## IS: 2911 (Part I/ Sec 1) - 1979

**B-1. GENERAL**

**B-1.1** [illegible]

**B-1.2** [illegible]

where

[illegible]

Where $W$ is greater than $P_e$ and the pile is driven into penetrable ground,

$$\eta = \frac{W + P_e^2}{W + P}$$

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## Practices for Dynamic Pile Formula
## 桩动荷载作用下的公式
## IS: 2911 (Part I/ Sec 1) - 1979

Where $W$ is less than $P_e$ and the pile is driven into penetrable ground

$$\eta = \frac{W + P_e^2}{W + P} - \left(\frac{W - P_e}{W + P}\right)^2$$

The following are the values of $\eta$ in relation to $e$ and to the ratio of $P/W$:

| Ratio of $P/W$ | $e = 0·5$ | $e = 0·4$ | $e = 0·32$ | $e = 0·25$ | $e = 0$ |
|---|---|---|---|---|---|
| ½ | 0·75 | 0·72 | 0·70 | 0·69 | 0·67 |
| 1 | 0·63 | 0·58 | 0·55 | 0·53 | 0·50 |
| 1½ | 0·55 | 0·50 | 0·47 | 0·44 | 0·40 |
| 2 | 0·50 | 0·44 | 0·40 | 0·37 | 0·33 |
| 2½ | 0·45 | 0·40 | 0·36 | 0·33 | 0·28 |
| 3 | 0·42 | 0·36 | 0·33 | 0·30 | 0·25 |
| 3½ | 0·39 | 0·33 | 0·30 | 0·27 | 0·22 |
| 4 | 0·36 | 0·31 | 0·28 | 0·25 | 0·20 |
| 5 | 0·31 | 0·27 | 0·24 | 0·21 | 0·16 |
| 6 | 0·27 | 0·24 | 0·21 | 0·19 | 0·14 |
| 7 | 0·24 | 0·21 | 0·19 | 0·17 | 0·12 |
| 8 | 0·22 | 0·20 | 0·17 | 0·15 | 0·11 |

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## Practices for Dynamic Pile Formula
## 桩动荷载作用下的公式
## IS: 2911 (Part I/ Sec 1) - 1979

$P$ is the mass of the pile, anvil, helmet, and follower ( if any ) in tonnes.

Where the pile finds refusal in rock, 0·5 $P$ should be substituted for $P$ in the above expressions for $\eta$.

$e$ is the coefficient of restitution of the materials under impact as tabulated below:

a) For steel ram of double-acting hammer striking on steel anvil and driving reinforced concrete pile, $e$ = 0·5.

b) For cast iron ram of single-acting or drop hammer striking on the head of reinforced concrete pile, $e$ = 0·4.

c) Single-acting or drop hammer striking a well-conditioned driving cap and helmet with hard wood dolly in driving reinforced concrete piles or directly on the head of timber pile, $e$ = 0·25.

d) For a deteriorated condition of the head of pile or of dolly, $e$ = 0.

## Determination of Depth of Fixity of Piles
## 桩的嵌入深度的确定
## IS: 2911 (Part I/ Sec 1) - 1979

For determining the depth of fixity for calculating the bending moment induced by horizontal load, the following procedure may be followed.

Estimate the value of the constant of modulus of horizontal subgrade reaction $n_h$, or the modulus of subgrade reaction $K$ of soil from Table 1 or Table 2.

Determine from appropriate graphs given in Fig. 3 and 4 the value of $L$, the equivalent length of cantilever, giving the same deflection at ground level as the actual pile.

TABLE 1 TYPICAL VALUES OF $n_h$

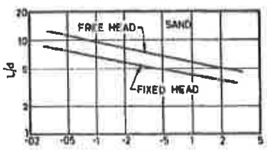
| SOIL TYPE | $n_h$ in kg/cm³ Dry | Submerged |
|---|---|---|
| Loose sand | 0·260 | 0·146 |
| Medium sand | 0·775 | 0·526 |
| Dense sand | 2·076 | 1·263 |
| Very loose sand under repeated loading | — | 0·041 |

TABLE 2 TYPICAL VALUES OF $K$ FOR PRELOADED CLAYS

| UNCONFINED COMPRESSION STRENGTH kg/cm² | RANGE OF VALUES OF $K$ kg/cm² | PROBABLE VALUE OF $K$ kg/cm² |
|---|---|---|
| 0·2 to 0·4 | 7 to 42 | 7·75 |
| 1 to 2 | 32 to 65 | 48·79 |
| 2 to 4 | 65 to 130 | 97·75 |
| 4 | — | 195·46 |

## Determination of Depth of Fixity of Piles
## 桩的嵌入深度的确定
## IS: 2911 (Part I/ Sec 1) - 1979

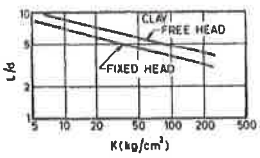
IS : 2911 ( Part I/Sec 1 ) - 1979




$L$ = Equivalent length of cantilever giving the same deflection at ground level as the actual pile.
$d$ = Diameter of the pile.

FIG. 3 $L/d$ VERSUS $n_h$ FOR EQUIVALENT CANTILEVER LENGTH

## Determination of Depth of Fixity of Piles
## 桩的嵌入深度的确定
## IS: 2911 (Part I/ Sec 1) - 1979




$L$ = Equivalent length of cantilever giving the same deflection at ground level as the actual pile.
$d$ = Diameter of the pile.

FIG. 4 $L/d$ VERSUS $K$ FOR EQUIVALENT CANTILEVER LENGTH

## Determination of Depth of Fixity, Lateral Deflection and Maximum Moment of Laterally Loaded Piles
## 确定水平受荷桩的嵌入深度、水平位移和最大弯矩
## IS: 2911 (Part I/ Sec 1) - 1979

**B-1. DETERMINATION OF LATERAL DEFLECTION AT THE PILE HEAD AND DEPTH OF FIXITY**

**B-1.1** The long flexible pile, fully or partially embedded, is treated as a cantilever fixed at some depth below the ground level ( *see* Fig. 2 ).

**B-1.2** Determine the depth of fixity and hence the equivalent length of the cantilever using the plots given in Fig. 2.

where

$T = \sqrt[5]{\frac{EI}{K_1}}$ and $R = \sqrt[4]{\frac{EI}{K_2}}$ ( $K_1$ and $K_2$ are constants given in Tables 2 and 3 below, $E$ is the Young's modulus of the pile material in kg/cm² and $I$ is the moment of inertia of the pile cross-section in cm⁴ ).

## Determination of Depth of Fixity, Lateral Deflection and Maximum Moment of Laterally Loaded Piles
## 确定水平受荷桩的嵌入深度、水平位移和最大弯矩
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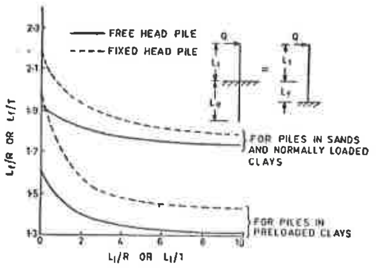


## Determination of Constant K1 and K2
## 常数K1和K2的确定

TABLE 2 VALUES OF CONSTANT $K_1$ ( kg/cm³ )
( *Clause* B-1.2 )

| TYPE OF SOIL | VALUE Dry | Submerged |
|---|---|---|
| Loose sand | 0·260 | 0·146 |
| Medium sand | 0·775 | 0·525 |
| Dense sand | 2·075 | 1·245 |
| Very loose sand under repeated loading or normally loading clays | — | 0·040 |

TABLE 3 VALUES OF CONSTANT $K_2$ ( kg/cm² )
( *Clause* B-1.2 )

| UNCONFINED COMPRESSIVE STRENGTH IN kg/cm² | VALUE |
|---|---|
| 0·2 to 0·4 | 7·75 |
| 1 to 2 | 48·80 |
| 2 to 4 | 97·75 |
| More than 4 | 195·50 |

## Developments In Foundation Engineering 基础工程的发展

- Foundation Technologies 基础技术
- Equipment设备
- Materials材料
- Construction Methods施工方法

## Foundation Equipment基础设备

**Introduction简介**

- Equipment plays a crucial role in any special foundation construction.
- 设备在任何特殊的基础建设中起着至关重要的作用。
- It is not possible to implement new foundation technologies without these equipments.
- 没有这些设备，就不可能实现新的基础技术。

**Difficulties in Procuring 采购的困难**

- Most of them are manufactured in Europe and other developed countries.
- 大部分设备在欧洲和其他发达国家生产。
- Transportation and customs duty add on to their already high capital cost inhibiting procurement of required numbers in to our country. 运输、关税和设备本身昂贵的价格抑制了我们国家的采购量。

## Foundation Equipment基础设备

**Difficulties in Executing and Implementing 执行和实施方面的困难**

- Clients and consultants leave this important aspect of selecting and implementing technologies and importing equipment to the general contractors and general contractors in turn expect the subcontractors to invest their time and money on them.
- 业主和顾问把选择和实施技术和进口设备这些重要方面留给承包商去做，反过来承包商也希望更多的时间和金钱被投入到他们身上。
- There is a general hesitation among the construction companies to invest in foundation equipment and technologies, training of their staff, etc., and instead get their foundation works carried out by "foundation sub-contractors."
- 建筑公司普遍不愿意投资基础设备、技术和培训员工等，而是把他们基础工程外包给"基础承包商"去做。
- The reason being forwarded is that such a heavy investment in foundation equipment is disproportionate to the overall share of foundation works in a project and continuous usage of such capital intensive equipments is doubtful.
- 原因是对基础设备的大量投资与项目中基础工程的整体份额不成比例，而且这种资本密集型设备常不能重复使用。

## Foundation Equipment基础设备

**Continued…接上页…**

- This project-to-project approach may be the sole reason why general contractors do not develop their foundation execution capabilities.
- 这个PTP方法可能是承包商不愿开发基础的唯一原因。
- Many times there is a conflict of interest between main contractor and his subcontractor.
- 很多时候主承包商和他的分包商之间存在利益冲突。
- While the main contractor would like to get his foundation works completed according to specifications in a very economical and time bound manner the subcontractor may have a tendency to finish his part in the least possible time leading to possible quality issues.
- 主承包商希望可以根据规范以一种非常经济和节省时间的方式完成基础工程，分包商可能会倾向于在尽可能少的时间内完成其应做部分，从而导致潜在的质量问题。

## Foundation Equipment基础设备

**Continued…接上页…**

- It will be too expensive to our country to leave this important aspect to an agent or to a subcontractor as they may not feel the urgency or have the financial muscle required to invest in a large fleet of foundation equipment that the country needs for its overall development at a faster pace.
- 对我们国家来说，把这个重要的方面留给一个代理或分包商代价非常高昂，因为他们往往没有紧迫感和投资大型基础设备应有的经济实力，但是我们国家的整体快速发展需要基础设备方面的投资。
- Investments by subcontractors are expectedly market and demand driven and not necessarily according to our country's overall needs in the foreseeable future.
- 可以预见，分包商的投资将由市场和需求驱动，而不一定根据我们国家的总体需求。

## Foundation Equipment基础设备

**Significant Change and Progress重大改革和进展**

- Efforts by National Highways Authority (NHAI) of India, Delhi Metro Rail Corporation (DMRC) and other client organizations have made it mandatory to employ high productive equipment in their projects.
- 印度国家公路管理局（NHAI）、德里地铁公司（DMRC）和其他客户组织强制在项目中使用高生产率的设备
- Over the last 10 to 12 years period the number of hydraulic rotary pilings in our country has risen from nearly zero to around 500 numbers.
- 在过去的10到12年里，我们国家的液压旋转桩的数量已经从接近零增长到500个。
- This number needs to be at least three to four times if all clients and consultants impose hydraulic piling rigs for bored piling works in their projects.
- 如果所有业主和咨询公司都要在他们的项目中为钻孔打桩工程设置液压打桩钻机，则该数量必须至少增加三到四倍。

## Conventional Rigs传统钻机

- Both types of these driven piles are installed using drop hammers mounted on A-Frames or steel lattice towers held in position by guy wires.
- 这两种类型的驱动桩都是安装在A型框架上的落锤或通过拉索固定在适当位置的钢格塔上。
- These are moved on skids or pipe rollers which are laborious and time consuming. 它们在滑道或管辊上移动，非常费力且耗时。
- Driving energy is imparted by drop hammers lifted and dropped with the aid of diesel engines. 借助于柴油发动机提升和下降的落锤可以传递驱动能量。

## Limitations of Equipment's 设备的局限性

- Slow Mobility机动性差
- Difficult Maneuverability操纵困难
- Large Number of Labour劳动力需求量大
- Limited Hammer Capacity落锤质量有限
- Inefficient Energy Transfer to Pile Head能量转移到桩头的效率低
- Instability, etc. 不稳定性, 等等

**Drawback缺点**

- Pile installation speed and capacity to drive deep are quite low
- 桩的安装速度慢、没有把桩击入较深深度的能力

**Integrated Driven Piling Rig with Hydraulic Hammer**
**液压锤驱动打桩机**

## Applications应用

- KGD6 (Krishna Godavari Dhirubhai 6) Onshore Gas Terminal Project in Kakinada, India
- 印度卡基纳达KGD6 (Krishna Godavari Dhirubhai 6)陆上天然气终端项目。
- Precast concrete piles- 1.0 million meters- depth 48 to 50 m-dense sand.
- 预制混凝土桩-100万米-深度48-50米-密砂.
- Productivities increased by 2 to 3 times that of conventional rigs.
- 生产力提高到传统钻机的2至3倍。
- Number of workers required per rig dropped rom 12 or 13 in the case of conventional rigs to 5 or 6 for integrated rigs.
- 常规钻机每台钻机的工人数量减少了12或13个，而综合钻井平台减少了5到6个。
- Unit driving cost (-10%).
- 单位台班成本 (-10%).

## Mechanical Pile Splices for Precast Piles 预制桩机械装配

- Precast piles are normally driven in segments of suitable lengths to take care of the handling stresses.
- 预制桩通常按合适的长度分段安装来解决应力问题。
- These sections are joined by either field welding of embedded steel end plates or mechanical splices to either end of the two pile segments to be joined at the pile location.
- 这些部分通过嵌入式钢板或机械接头的现场焊接连接到两个桩段的任一端。
- Field welding and cooling of joints takes time. 现场焊接和接头冷却需要时间。
- Possibility of quality issues arising from field welding.现场焊接可能产生的质量问题。

## Applications应用

'Sure Lock" mechanical splices (USA) "Sure Lock" 机械拼接 (美国)

- HMCPCL piling site in Haldia (West Bengal) HMCPCL 桩施工于霍尔迪亚 (孟加拉西部)
- RIL KGD6 project at Kakinada (Andhra Pradesh) RIL KGD6 工程于卡基纳达 (安德拉邦)
- Dharma port site in coconut island (Orissa). 椰子岛的达摩港(奥里萨邦)

## Advantages优势

- The mechanical splicing would take hardly 5 minutes, welded joint takes about 120 to 180 minutes.
- 机械拼接需要5分钟，焊接接头大约需要120到180分钟。
- High quality and high strength. 高质量和高强度。
- Saving in labour cost. 节省劳动力成本。

Sure Lock Mechanical Pile Splice for Precast Pile Segment
预制桩段的锁紧机械桩接头

## Integrated Multi-Purpose Piling Rigs
## 综合多用途打桩机

### Application

- High capacity integrated multipurpose hydraulic piling rigs with hydraulic hammers- First time- Indian Oil Corporation Ltd. project site in Panipat, India.
- 高强度综合多功能液压打桩机-第一次使用-印度石油公司在印度帕尼帕特的项目。
- An extensive training was carried out to the entire team at site to ensure that the speed of fast driving equipment is matched by timely supply of pile reinforcement cage and concrete.
- 在现场对整个团队进行培训，以确保快速钻孔技术与桩的钢筋笼和混凝土的供应速度相匹配。

### Advantages 优势

- 30 to 35 piles per day per rig每台钻机每天可打30至35根桩

## Precast Piling Project- RIL KGD6 project Benefits
## 预制桩工程- RIL KGD6 工程优势

- Economical pile foundation system 经济的桩基础系统
- Reduction in uncertainties of pile driving减少打桩的不确定因素
- Improved confidence in the pile behavior under load 桩的载荷能力增强
- Enabled smooth and trouble free piling operations in such a mammoth piling job of more than 1.0 million meters在超过100万米的庞大打桩工作中可实现平稳无故障的打桩作业
- Selection of appropriate and safe driving mechanism打桩机制合适且安全

Panipat Refinery, Indian Oil Corporation, India Panipat
炼油厂，印度石油公司，印度

## Hydraulic Pile Head Breakers
## 液压桩头破碎机

- Once concrete piles are installed to the required depths the top portion has to be cut-off up to the required level below ground level to enable pile embedment in to the pile cap.
- 一旦混凝土桩打到设计深度，桩顶部分必须被切断以达到桩顶低于地面的要求，以便将桩嵌入到桩帽中。
- The method employed in our country is manual labour with hammer and chisel or jack hammers.
- 我国采用的方法是人工用锤子、凿子或气锤施工。
- With projects size and corresponding pile numbers increasing significantly in recent years the above methods were found to be time consuming.近年来，随着项目规模和相应的桩数显著增加，上述方法非常耗时。

### Applications

- RIL KGD6 (Krishna Godavari Dhirubhai 6), Kakinada, India
- IOCL Panipat, India

## Advantages优势

- Where the reinforcement is not very congested these hydraulic breakers are found to be very effective in cutting down on labour as well as time.
- 在钢筋布置不是很拥挤的地方，液压破碎机在节约劳动力和施工时间方面效果非常显著

Hydraulic Pile Head Breaker
液压破碎机

## Hydraulic Rotary Piling液压旋转桩

- Several of our steel industries have been dumping the blast furnace slag and other industrial by-products in open areas around the existing plants for several decades resulting in large areas of fill with thicknesses ranging from a few meters to as high as 20 meters.
- 几十年来，一些炼铁厂一直在其周围开阔地带倾倒高炉矿渣和其他工业副产品，导致这些废料从几米到20米不等厚度的大面积堆积。
- With the current large scale expansion of steel industry fresh units are being set up in these filled up areas. 随着钢铁行业的大规模扩张，废料堆积面积不断增加。
- Because of heavy loads and sensitivity to differential settlements the plant structures and equipment are generally supported on bored cast-in-situ piles.
- 由于荷载过大和对不均匀沉降的敏感性，工厂结构和设备的造成的荷载一般都由钻孔现浇桩支撑。
- Conventional tripod-winch-chisel/bailer type of boring has been in use for several years.
- 传统的三脚架 - 绞车 - 凿子/凿式镗孔已经被使用多年。

## Application应用

- SAIL, Burnpur, India
- 35000 bored piles of 550 mm diameters and around 20 m length were installed with both rotary piling rigs and conventional tripod rigs.
- 35000个直径550mm长20m的钻孔灌注桩通过旋转打桩钻机和传统三脚架钻机施工。
- While the boring progress with tripods is around 10 m/day of 2 shifts through the slag rotary piling rigs are able to drill around 60m/per day of 2 shifts which is equivalent to 3 piles/day/rig. 三脚架钻机钻孔速度大概是10 m/日/2台班，矿渣旋转打桩机则是60m/日/2台班，相当于3 根桩/日/台班。
- Temporary casings are being used to stabilize the walls of the pile bore.
- 临时套管用于稳定孔壁。

### Advantages优势

- Increased productivity 提高生产效率

Sail, Burnpur

## Use of Special Polymers to Stabilize Walls of Pile Bore 使用特殊聚合物稳定桩孔壁

- Temporary or permanent steel liners are being used to stabilize the walls of the slag fill in the steel industry. 钢铁行业用临时或永久的钢衬层来稳定矿渣填埋坑的坑壁。
- This method slows down the boring rate. 这种方法减慢了钻孔速度。
- Through several trials by a team from L&T and the manufacturer of the special polymers from USA a polymer mix was developed and is being used successfully at TISCO Jamshedpur site.
- 通过来自L&T的一个小组和美国特殊聚合物制造商的多次尝试，一种混合聚合物被研发出来并成功的在Jamshedpur的TISCO工程中应用。

### Advantages优势

- Improved piling productivity from 10 m/day (2 shifts) with conventional tripod rigs to 75 m/day for 550 mm diameter piles and from 3 m/day to 75 m/day for 1000 mm diameter piles.
- 提高打桩效率，从传统三脚架钻机的10 m/日 (2 台班)提高到75 m/日（ 550 mm直径桩），3 m/日提高到 75 m/日（1000 mm 直径桩）。

## Use of Side Grip Vibro-Cum Impact Hammer 侧握式冲击锤的使用

- Sheet piling is not very common in India and this is posing major problems in both availability of right type of sheet piles as well as sheet pile driving equipment. 板桩在印度并不常见，原因是合适的类型板桩和板桩钻孔设备的可获得。
- Drop hammer, impact hammers and modern hydraulic or electrical type Vibro hammers are being employed.
- 落锤、冲击锤和液压或电式振动锤目前使用较多。
- It suffers some setback leading to difficulties in driving to required depths and at times leads to collapse of the walls of excavation.
- 当打桩是遇到一些阻碍会导致难以到达所需的深度并且有时会导致孔壁的坍塌。

## Application应用

- Side grip Vibro hammer together with reversible type impact hammer was imported from Finland. 从芬兰进口的侧握式振动锤和可逆式冲击锤。
- The equipment mounted on excavator is found to improve handling ease and installation speed. At L&T's Dhamra Port project Arselor AU20 sheet piles of 12 m lengths were installed for the wagon tippler location at a rate of 100 sq-m/day of one 12 hour shift.
- 安装在挖掘机上的设备可以提高装卸速度。在 L&T's Dhamra 港的项目Arselor AU20中12m长板桩的安装速度为100平方米/日（12小时轮班）。

## Trench Cutter沟槽切割机

- Dam cut-off walls are being installed in India with the help of Reverse Circulation Rigs of old designs. 印度使用老式反循环钻修筑机大坝防渗墙。
- National Hydro-Electric Power Corporation (NHPC)- Hydromill/Trench Cutter equipment.

**Application 应用**

- At NHPC Parbati Hydro-Electric project site a 45 meter deep dam cut-off wall in plastic concrete was constructed 5 months ahead of schedule using Trench Cutter technology. 国家水电电力公司的Parbati水电项目中使用沟槽切割技术提前5个月建造了一道用塑性混凝土浇筑的45m深堤坝的防渗墙。

**Advantages优势**

- These equipments bring speed and quality to the cut-off wall construction.
- 这些设备提高了防渗墙的施工速度和质量。

## Automation for Data Logging and Pile Installation Monitoring Systems 自动化数据记录和桩安装监测系统

- Data logging and pile installation monitoring system was introduced on Multipurpose Integrated driven piling rigs to eliminate manual recording and reporting and to improve the installation process of driven cast-in-situ piles.数据记录和桩安装监测系统被用在多用途综合打桩机上来代替人工记录和报告以完善钻孔灌注桩的施工。
- Manual data recording errors are eliminated and it is also possible to send the data from the piling rig to any desired place through internet.消除人工记录数据的误差，也使通过互联网将由打桩机获得的数据传输至需要的地方成为可能。

## Vibro-Compaction for Structures 振动压实结构

- Various man made obstructions, slag skulls, etc. were being encountered in a slag fill making pile boring very difficult and time consuming, at one of the steel plant sites. 在一个钢铁厂工地上的矿渣填埋处，遇到各种各样的人为障碍，矿渣等，这些使得钻孔变得非常困难和费时的。
- Vibro compaction trials were carried out in the heterogeneous slag fill.
- 振动压实试验是在各向异性的矿渣中进行的。
- From various field density tests, laboratory shear box tests and field footing load tests (1.3 m × 1.3 m size) it is observed that slag fill can be well compacted by Vibro compaction technique resulting in high allowable bearing pressures. 从各种现场密度测试、实验室剪切箱试验和现场基础负荷试验（1.3 m × 1.3 m）中，通过振动压实技术，可以很好地压实矿渣，从而达到较高的承压能力。
- These trials if accepted by client and consultant would pave the way to minimize or altogether eliminate the necessity to support structures on piles.如果客户和顾问接受这些试验，将为最小化或完全消除支持桩上结构的必要性铺平道路。

- Construction Industry in India is poised for a major contribution to the rapid development of various sectors of India's economy. 印度的建筑业将为印度经济的各个部门的快速发展做出重大贡献。
- There ~~is an urgent need for the current foundation technologies and practices to ensure that they~~ do not apply breaks to the overall growth process. 当前的基础技术和实践是迫切需要的，以确保它们不会中断整体增长趋势。
- The latest technologies and processes are listed and the most relevant to India are recommended. 列出了最新的技术和工艺，并提出了与印度最相关的技术和工艺。
- The advantages of a team work involving the client, consultant and the contractor to execute a major piling project that enabled speed, quality and economy through a process approach are highlighted.包括客户、顾问和承包商来执行一个打桩项目的团队工作的优势是，通过一个过程使得速度、质量和经济得以实现。
- Steps required to speed up the implementation of latest foundation technologies are suggested.
- 建议加快实施最新基础技术的步伐

## Suggested Foundation Technologies 基础技术推荐

1. Precast Piling with factory made piles, mechanical pile splices and integrated piling rigs equipped with energy efficient impact hammers and data logging and monitoring systems工厂预制桩、配备了节能的冲击锤和数据记录和监测系统机械桩拼接和集成打桩机。
2. Driven cast-in Situ Piling with integrated piling rigs equipped with energy efficient impact hammers, casing extraction systems and data logging and monitoring systems配备有节能的冲击锤、套管提取系统和数据记录和监测系统的综合打桩机。
3. Sheet Piling板桩
4. Deep Soil Mixing深层搅拌
5. Jet Grouting喷射灌浆
6. Rapid Impact Compaction快速冲击压实
7. Mass Stabilization with automatic dosing, mixing and monitoring systems自动配料、搅拌和监测系统

9. Hydraulic Pile Head Breakers液压桩头破断器
10. Screw Piles/Helical piles螺旋桩
11. Self Compacting Concrete自密实砼
12. Ground Improvement with Vibro-Compaction/Vibro-Replacement振动-压实/振动-更换的地基处理方式
13. Diaphragm walls with Kelly/Mechanical/Hydraulic grabs/Trench Cutter or equivalent, with Slurry Handling/Separation Systems, Concrete Batching Plant带阀/机械/液压/沟槽切割刀或同等材料的隔膜墙，带有泥浆搅拌/分离系统，混凝土搅拌装置
14. Modern Testing Systems for integrity and load carrying capacity of Piles, ex., Pile Integrity (PIT), Cross-Hole, Pile Driving Analyzer (PDA), Embedded load cell systems, etc.现代桩的整体性和承载能力的测试系统如：桩完整性（PIT）、跨孔、桩驱动分析仪（PDA）、嵌入式加载单元系统等

Client- CCE ( R & D) DELHI

AT SSPL Complex Timarpur , Delhi

Type- Cast In Situ Concrete Piles

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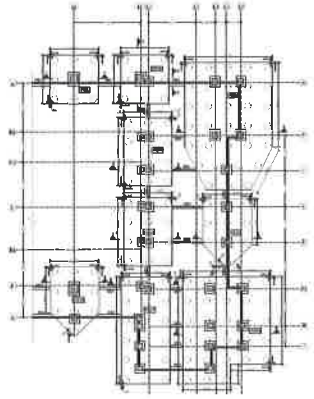

General Arrangement of Pile Cap

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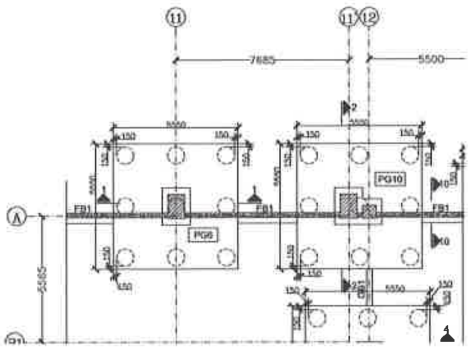


Enlarged View-Part Plan of General Arrangement Plan

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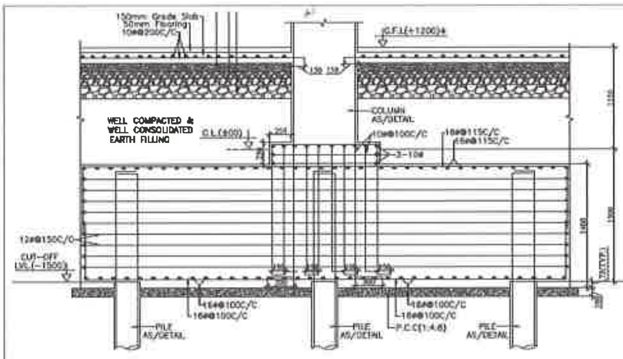


Section 1-1 Pile Cap

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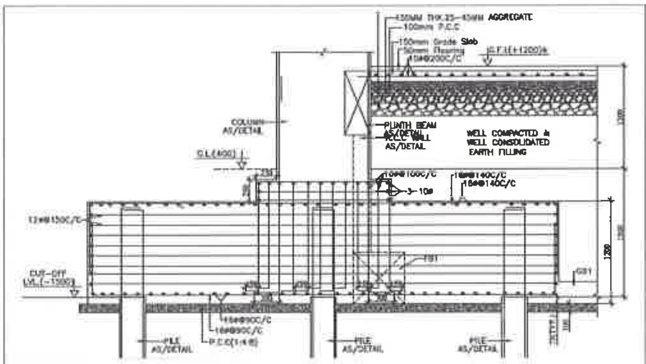


Section 2-2 Pile Cap

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Client- Delhi Metro Rail Corporation

Project- Okhla Phase III

Line 8

Janakpuri West to Botanical Garden

Type-Cast In Situ Concrete Piles

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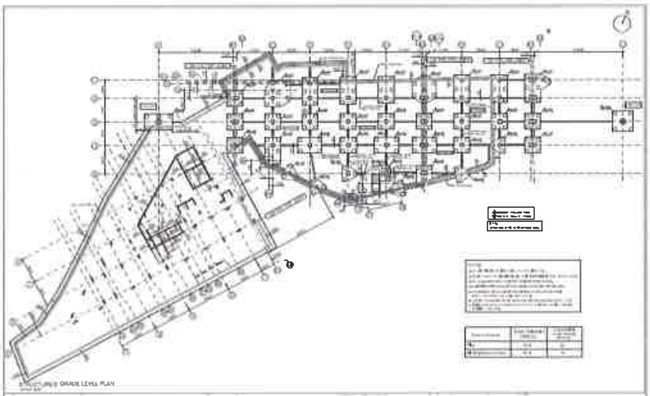

Pile Foundation Layout

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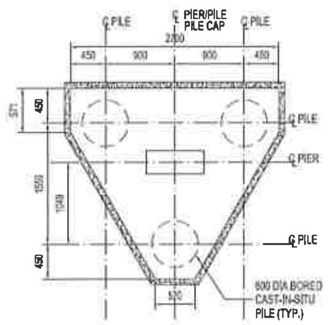


Pile Cap Arrangement
No. of Piles -03

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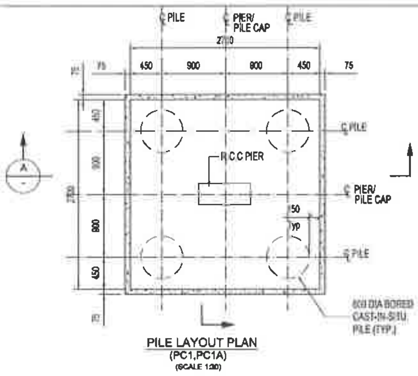
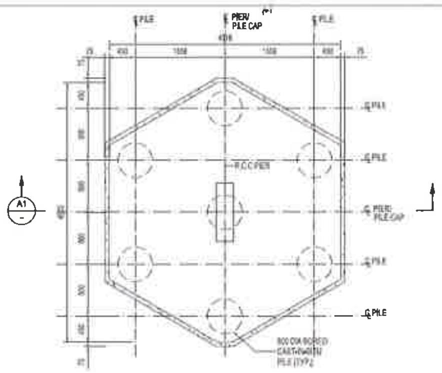


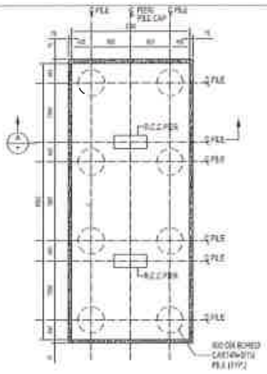

Pile Cap Arrangement
No. of Piles -04

DELHI TECHNOLOGICAL UNIVERSITY, DELHI, INIDA 76



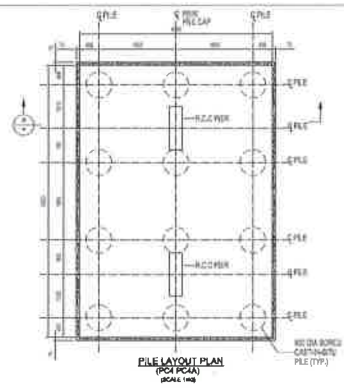

Pile Cap Arrangement
No. of Piles-06

DELHI TECHNOLOGICAL UNIVERSITY, DELHI, INIDA 77



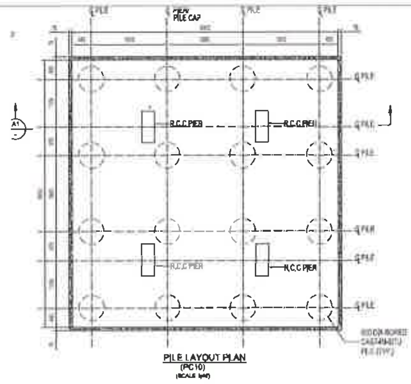
Pile Cap Arrangement
No. of Piles-08

DELHI TECHNOLOGICAL UNIVERSITY, DELHI, INIDA 78



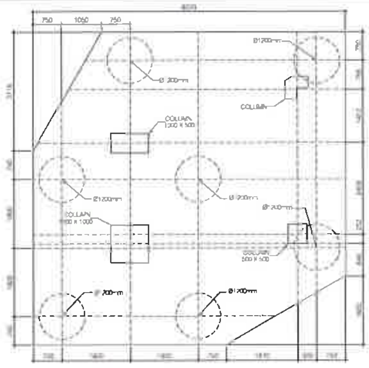

Pile Cap Arrangement
No. of Piles-12

DELHI TECHNOLOGICAL UNIVERSITY, DELHI, INIDA 79



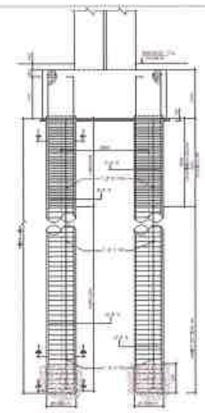

**Pile Cap Arrangement**
**No. of Piles-16**

DELHI TECHNOLOGICAL UNIVERSITY, DELHI, INDIA 80



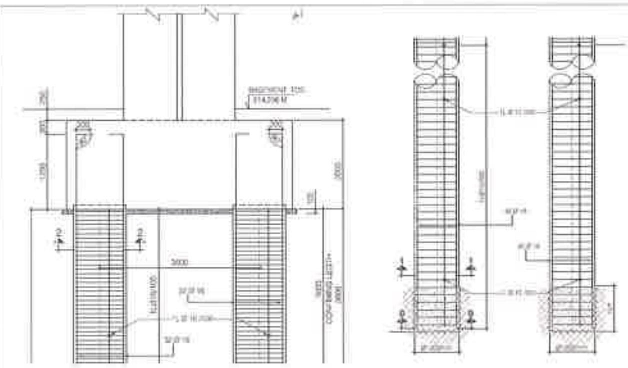

**Pile Foundation Layout**
**No. of Piles-07**

DELHI TECHNOLOGICAL UNIVERSITY, DELHI, INIDA 81



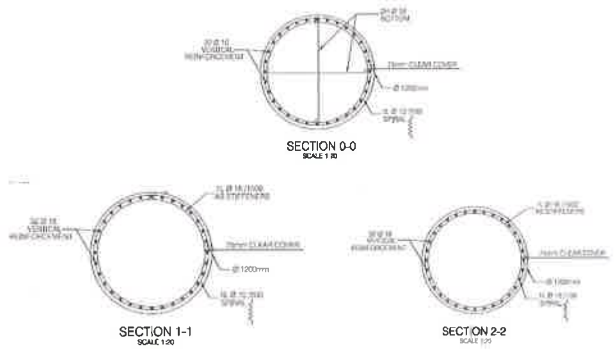
**Sectional Elevation**

DELHI TECHNOLOGICAL UNIVERSITY, DELHI, INDIA 82



**Enlarged View**

DELHI TECHNOLOGICAL UNIVERSITY, DELHI, INIDA 83




**Sections 1-1, 2-2, 3-3**

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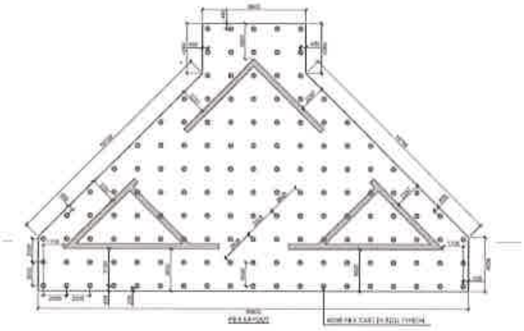
**Client- Lucknow Development Authority**

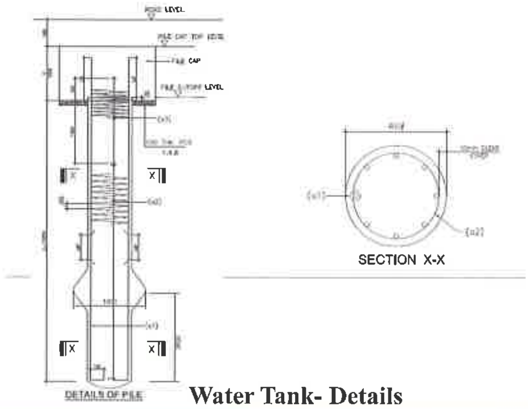
**Project- Master Planning of Chak Gangeria**

**AT Lucknow**

**Type- Cast In Situ Concrete Piles**



Pile Layout Plan- Water Tank

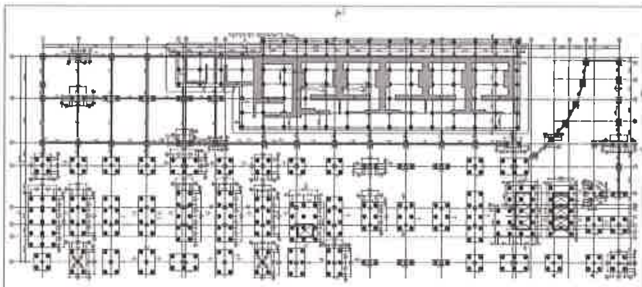



Water Tank- Details

Client- Uttar Pradesh Rajkiya Nirman Nigam

Project- High Level Cancer Institute at Lucknow

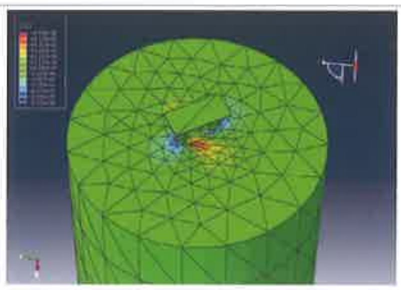
Type- Cast In Situ Concrete Piles



Proposed layout of High Level Cancer Institute Lucknow

## Pile Groups Under Torsional Loads
## 受扭矩作用的群桩

- Not a well investigated area world wide在全世界都不是一个有很好的研究进度的领域
- The pile foundation groups (large structures) 群桩基础(大型结构)
  - Machine foundation on pile group桩群基础上的机械基础
  - Offshore platforms海上平台
  - Wind turbines风力涡轮机
  - Bridges桥梁
  - Railway embankment铁路路基
  - Traffic and signal pole structures 交通和信号杆结构
  - High-rise buildings 高层建筑



Pile Group Under Torsional Load