ABSTRACT: Construction Industry in India is poised for a major contribution to the rapid development of various sectors of India’s economy. There is an urgent need to review the current foundation technologies and practices to ensure that they do not apply breaks to the overall growth process. The latest technologies and processes are listed and the most relevant to India are recommended. The experiences of the author with some of these technologies in his projects are presented. 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. Steps required to speed up the implementation of latest foundation technologies are suggested.

1. INTRODUCTION
Foundation engineering practice in our country is still in a nascent stage while the developments in foundation technologies, equipment, materials and construction methods in the advanced countries such as the countries of Europe, USA, Japan etc., are far ahead. While our knowledge and research in the geotechnical engineering may be comparable with those in the advanced countries, the same cannot be said about the foundation engineering and construction practices. A lot needs to be done on priority to ensure that the foundation works in every project, be it India’s infrastructure or industry, do not hinder the overall progress of quality construction and pace of development of our country. Some of the issues are discussed in the following paragraphs with the hope that if proper attention is paid at the national level and action initiated geotechnical engineering practices in our country can be elevated to the international level and positive benefits can be reaped in the form of accelerated construction of India’s infrastructure.

2. SHARE OF FOUNDATIONS IN A CONSTRUCTION PROJECT
One reason why generally construction companies, clients, and consultants do not focus on foundation technologies could be the fact that in majority of cases the cost of foundations ranges from 1 to 10% of the civil construction cost of a project. Even in some special cases such as marine structures and bridges, where the foundation costs can be as high as 50% of the cost of the constructed facility foundations are still being executed following the outdated, slow and labour intensive methods and equipment. There are numerous cases where failure or poor performance of a foundation has led to erosion of the total value of the constructed facility. It is therefore important that instead of according low priority to foundations based on their relative cost focus should be redirected to consequences of a poor foundation.

It is all the more important to realize that quality and speed are essential in the case of foundation works because of the simple fact that in most of the foundation works we do not see what we construct. Technologies are available to address these issues, where the quality and speed of foundations can bring significant savings to the project (Rama Krishna 2009).

3. LATEST TECHNOLOGIES AND PROCESSES
It is noteworthy to mention here that even a very advanced country such as USA had organized a geotechnical engineering “scan tour” comprising a team of geotechnical and bridge design experts from Federal, State, academic, and private industry sectors, to visit Europe in 2002 with an objective to identify and evaluate innovative European foundation technologies for accelerated construction and rehabilitation of bridge and embankment foundations in USA. This Scan team identified as many as 30 technologies and up to 15 processes which would meet their objective and also observed that many of these technologies offer a potential for cost savings and in a majority of cases, an improvement in quality over current practice (FHWA-PL-03-014, 2003). These are listed below since, in the opinion of the author, these technologies and processes are equally relevant to our construction industry and would elevate the foundation engineering practice in our country:

3.1 Foundation Technologies
(a) Embankments on Columns
(b) Light Weight Aggregates
(c) Deep Mixing (Lime-Cement) Columns
(d) Mass Stabilization
(e) Geotextile-Encased Columns (GEC)
It is not possible to implement technologies and methods if all clients and consultants impose hydraulic rotary bored piling rigs in to India. Thanks to the efforts by National Highways Authority (NHAI) of India, Delhi Metro Rail Corporation (DMRC) and other client organizations who have made it mandatory to importing of hydraulic rotary bored piling rigs. As a result transportation and customs duty add on to their already high capital cost inhibiting procurement of required numbers in to our country. It is generally observed that 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. 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 subcontractors.” 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. This project-to-project approach may be the sole reason why general contractors do not develop their foundation execution capabilities. Alas, many times there is a conflict of interest between main contractor and his subcontractor. 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.

It is too risky to expect small time subcontractors to take the responsibility of what the country badly needs. We are already very much behind in the execution of foundation works using latest technologies, equipment and methods. If we do not take up this matter on top priority, construction industry is bound to suffer slippages, failures and eventually loss of time and investment. 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. Investments by subcontractors are expectedly market and demand driven and not necessarily according to our country’s overall needs in the foreseeable future. We have made significant but not sufficient progress in the case of client driven initiatives with regard to importing of hydraulic rotary bored piling rigs in to India. Thanks to the efforts by National Highways Authority (NHAI) of India, Delhi Metro Rail Corporation (DMRC) and other client organizations who have made it mandatory to employ these high productive equipment in their projects. 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. 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. It should be acknowledged here that the role being played by the representatives of equipment manufacturers and piling mentioned above without these equipments. Most of them are manufactured in Europe and other developed countries. As a result of the limited options available within our country (o) Automated Control QC Documentation of Installation. (n) Maintenance-Based Payment Procedure (m) Screw Piling (n) Combined Soil Stabilization (CSV) System (o) Accelerated Site Investigation (p) Continuous Flight Auger (CFA) Piles (q) Bored Piling—Cased Secant Pile (CSP) (r) Berlin Wall (Micro pile Wall) (s) Continuous Diaphragm Wall (CDW) (t) Hydro-Mill Diaphragm Walls (u) Reinforced Protective Umbrella Method (RPUM) Glass-Reinforced Plastic Bar (v) Pretunneling (w) Micro piling Rod Carousels (x) Rock Saw (y) Computer Controlled Consolidation Grouting (z) Turbo-Jets (aa) Horizontal Vacuum Consolidation (ab) Augeoa (ac) Dynamic Stiffness Gauge (ad) Higher Energy Compaction Impact Roller.

3.2 Processes and Approaches

(a) Public Relocation during Construction (b) Communication with the Public (c) Designer on Board during Construction (d) Contractor Involved in Design (e) Contractor/Designer QC/QA Required ISO 9000 (f) Real-Time Lab Testing and Data Storage (g) Real-Time Design, e.g., ADECO-RS, (Analysis of Controlled Deformation) (h) 10-Year Warranties/Insurance (i) Pile Load Test Programme/Certification for Screw Piling (Recommendations) (j) Self-Compacting Concrete (k) Prefabricated Bridge Parts (Bayonet Pipe Pile Connection) (l) Moving Completed Bridges on Site (m) Automated GPR for Pavement (n) Maintenance-Based Payment Procedure (o) Automated Control QC Documentation of Installation.

Because of the limited options available within our country an optimized foundation solution is becoming a rare event and consequently piling is becoming more common.

4. FOUNDATION EQUIPMENT

Equipment plays a crucial role in any special foundation construction. It is not possible to implement technologies
subcontractors is praiseworthy even though they do not match with what our country needs in the short and long terms.

China had acted very early and taken great visionary steps to prop-up their construction industry by promoting and facilitating joint ventures and other forms of cooperation between the equipment manufacturing industry of China and leading manufacturing companies of Europe, USA, etc., which enabled them build a robust infrastructure in a relatively short duration and also took the country to a commanding position even to supply cost effective advanced construction equipment and materials to India. The same is true about special foundation equipment as a result of which it appears that there is no need in China to import foundation equipment in to their country. This example of China is worth emulating by our country so that leading manufacturing companies of the world can set up their manufacturing base in India to promote the availability of advanced equipment at affordable prices. It is only then that the infrastructure can be developed at a faster pace.

5. DESIGN AND CONSTRUCTION ARE INSEPARABLE—OBSERVATION METHOD

Probably there is no other field of engineering where the design is an inseparable part of construction than the field of geotechnical engineering. The inherent variability in the type and engineering properties of soils encountered at any given project site baffles the designer of foundations. The construction quality and behaviour of a foundation or a geotechnical system largely depend on the way it is constructed and many times do not conform to the assumptions made while designing the foundation. Bored pile which is a very common foundation system adopted in India serves as a typical example. The designer may design a bored pile as a friction pile or an end bearing pile or as combination of both. But, while executing, if proper care is not taken and the design assumptions are not understood the piling contractor can produce a pile which may not conform to these assumptions. It is quite common in the case of friction piles to loose a significant part or all of the shaft friction by wrong boring method. In the case of end bearing piles it is all the more dangerous if the pile toe is not cleaned properly or if the soil at the pile tip does not conform to the design parameters, there is every chance that the completed pile would undergo substantial settlement before any meaningful capacity can be generated. The same is true in the case of driven cast-in-situ piles, sheet piles, diaphragm walls, etc. The importance of initial trials and installation for testing the workmanship, for arriving at design parameters, and for the finalization of method and equipment cannot be overstated. Mechanization and automation, Instrumentation and monitoring will lessen the risk to a large extent. For the design engineer to assure himself that his design basis and procedure are corroborated by the observations in the field he needs to closely associate himself suitably with the execution of foundation and geotechnical works. During the execution he may need to refine or revise his designs in order to bring safety as well as economy to the foundation and the structure it supports. Powderham & Peck (2000) had the following to say: “Ground engineering faces inherent uncertainty, so the ability to develop and exercise good judgement is fundamental. This demands an understanding of geology, soil mechanics, and soil structure interaction. In addition, an appreciation of the relationship between theory and practice, of the relevance of precedent, and of construction methods is vital. Relating design to construction is critical—success in addressing real problems demands getting the concept right and attending to details.” While delivering his 2001 Milton E. Bender lecture Dr. Z.C. Moh (Moh 2001) said, “For any physical infrastructure development, whether they are founded on ground, built in the ground or utilize earth material as construction material, the role of geotechnical engineering cannot be over-emphasized. However, geotechnical engineering, not like other branches of civil engineering, up to the present, still has not been developed into an exact science due to the complex nature of the earth. Sound geotechnical practice depends on integration of theory, reliable data, and experience. Observational method by utilizing field monitoring data during construction for design revisions is the best approach to achieve economy and safety in major infrastructure development.”

Powderham (2002) while strongly advocating the Observation Method underlined that traditional contractual conditions can separate design from construction and impede a team approach to the management of risk. Through three case histories he demonstrated that Observation Method also promotes innovation through:

(a) Stronger connection of design to construction  
(b) Increased safety during construction  
(c) Improved understanding of soil/structure interaction  
(d) Improvements in the use and performance of instrumentation  
(e) Higher quality case history data  
(f) Greater motivation and team work.

The author was closely associated with a major onshore gas terminal project, KGD6 at Kakinada, India where the client Reliance Industries Ltd., consultant D.V. Karandikar Associates, and the contractor Larsen & Toubro Ltd worked literally as a single team throughout the project to successfully and economically implement a large scale precast piling work (Vaidya, et al. 2007) following the process approach recommended by Bell et al. (2002). The process is similar to the Observation Method and has the following steps:

(a) Evaluate subsurface data and perform static pile capacity analysis  
(b) Select preliminary driving criterion using “wave equation” analysis  
(c) Drive probe (or indicator) piles across the site area using a Pile Driving Analyser (PDA) to evaluate capacity, driving stresses, and hammer performance  
(d) Evaluate and adjust the driving criterion based on the results of the PDA
(e) Drive static test pile(s) using the revised driving criterion
(f) Load test the test pile(s)
(g) Perform a final evaluation of the driving criterion for the production piles based on the load test results.

A comparison of the conventional approach and process approach is presented in Table 1.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Conventional approach</th>
<th>Process approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Calculate Theoretical Capacity</td>
<td>Calculate Theoretical Capacity</td>
</tr>
<tr>
<td>2.</td>
<td>Compute Set value Preliminary Drivability study</td>
<td>HILEY’s Formula Selection of Hammer &amp; Hammer Stroke</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENR formula Set calculation</td>
</tr>
<tr>
<td>3.</td>
<td>Static test Maintain load test Cyclic load test</td>
<td>PDA on Test piles</td>
</tr>
<tr>
<td>4.</td>
<td>Drive to set Fine tuning of driving criteria</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Drive Static Load test piles</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Static Load test on piles</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Final evaluation of capacity &amp; driving criteria based on PDA and static load test results</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Actual capacity seldom found out. Actual Capacity can be found, Savings in time &amp; Pile quantity</td>
<td></td>
</tr>
</tbody>
</table>

**6. RECENT EXPERIENCES**

Some of the recent experiences in the projects where the author and his team were involved in bringing a few technologies, equipment and materials are presented below. These initiatives have resulted in speedy and quality construction of foundations with significant cost savings. Training the front line and supervisory staff, exposing the field engineers to all aspects covering design to installation, and integrating all concerned from design to installation are the key factors contributing to the success of these initiatives.

**6.1 Integrated Driven Piling Rigs with Hydraulic Hammers**

Among the type of piles adopted in India bored piles are the most common ones. Driven cast-in-situ piles fall in to the second category in terms of popularity. Unfortunately precast driven piles are not very common even though they offer several advantages. 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. These are moved on skids or pipe rollers which is laborious and time consuming. Driving energy is imparted by drop hammers lifted and dropped with the aid of diesel engines. These equipments suffer from various limitations such as slow mobility, difficult maneuverability, large number of labour, limited hammer capacity, inefficient energy transfer to pile head, instability, etc. As a result of these limitations the pile installation speed and capacity to drive deep are quite low. In developed countries and several countries in the Far-East crawler mounted integrated driven piling rigs with highly efficient hydraulic hammers have been in use for a few decades (Fig. 1). These rigs have been introduced in KGD6 Onshore Gas Terminal Project in Kakinada, India to drive around 1.0 Million meters of precast concrete piles to depths of 48 to 50 m in to dense sand founding layer overcoming medium dense to dense sand layers at intermediate depths. Productivities increased by 2 to 3 times that of conventional rigs described above and number of workers required per rig had dropped to half (from 12 or 13 in the case of conventional rigs to 5 or 6 for integrated rigs). As a result the unit driving cost had also decreased significantly (10%).

Fig. 1: Integrated Driven Piling Rig with Hydraulic Hammer

**6.2 Mechanical Pile Splices for Precast Piles to Replace Field Welding of Pile Joints** (Fig. 2)

Precast piles are normally driven in segments of suitable lengths to take care of the handling stresses and very soft or very hard intermediate soil layers. 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.
It has been observed that the field welding and cooling of joints takes time. In addition, there is always a possibility of quality issues arising from field welding. When using conventional rigs such as the ones described in Para 6.1 above, entire piling gang and piling equipment are on standby while the field weld joint work is in progress. All these make the field weld joints unattractive both from time and cost points of view. “Sure Lock” mechanical splices from USA were introduced at HMCPCL piling site in Haldia and continued at RIL KGD6 project at Kakinada and currently at Dhamra port site. The productivity improvements were closely monitored and it is found that while the welded joint takes about 120 to 180 minutes the mechanical splicing would take hardly 5 minutes. The mechanical splice has the advantages of high quality and high strength. The need for a separate welding gang is also eliminated.

**6.3 Process Approach in Precast Piling Project**

As mentioned in paragraph 5 above process approach adopted at RIL KGD6 project resulted in the following benefits:

- Economical pile foundation system
- Reduction in uncertainties of pile driving
- Improved confidence in the pile behavior under load
- Enabled smooth and trouble free piling operations in such a mammoth piling job of more than 1.0 million meters
- Selection of appropriate and safe driving mechanism.

Together with initiatives in 6.1 and 6.2 there was a significant jump in productivity and cost savings to the client. Table 2 gives a comparison of conventional and integrated driven piling rigs.

**Table 2: Comparison of Precast Piling Rigs Performance**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Description</th>
<th>Integrated piling rig &amp; hydraulic hammers</th>
<th>‘A’ frame with drop hammer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>No of Equipment</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>2.</td>
<td>Total No. of Piles</td>
<td>13570</td>
<td>7048</td>
</tr>
<tr>
<td>3.</td>
<td>Total No. of R.M (Approx)</td>
<td>651360</td>
<td>338304</td>
</tr>
<tr>
<td>4.</td>
<td>Total No. of Months</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>5.</td>
<td>Productivity (Pile/Rig/Month)</td>
<td>85</td>
<td>41</td>
</tr>
<tr>
<td>6.</td>
<td>Productivity (R.M)/Rig/Month</td>
<td>4071</td>
<td>1990</td>
</tr>
<tr>
<td>7.</td>
<td>Piling Crew/Rig/Shift</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>8.</td>
<td>Total Man days of Crew</td>
<td>54000</td>
<td>91800</td>
</tr>
</tbody>
</table>

**6.4 Integrated Multi-Purpose Piling Rigs to Install Driven Cast-in-situ Piles (Fig. 3)**

High capacity integrated multipurpose hydraulic piling rigs with hydraulic hammers have been introduced first time at the Indian Oil Corporation Ltd project site in Panipat, India. 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. It is found that once clear work front is available it is possible to drive 30 to 35 piles per day per rig. There was also an opportunity to compare the performances of various types of equipment used for installing the same size and length of piles at the same site (Table 3).

**Table 3: Performance Comparison of Pile Driving Equipment for Driven Cast-in-Situ Piles**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Description</th>
<th>Integrated piling rig &amp; hydraulic hammers</th>
<th>Rigs on pipe rollers &amp; drop hammer</th>
<th>Crane mounted leader &amp; air hammer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>No. of Equipments</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2.</td>
<td>No of Piles</td>
<td>3925</td>
<td>1078</td>
<td>5600</td>
</tr>
<tr>
<td>3.</td>
<td>Running Metres (app)</td>
<td>76538</td>
<td>19404</td>
<td>100800</td>
</tr>
<tr>
<td>4.</td>
<td>No. of Months</td>
<td>10</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>5.</td>
<td>Productivity Pile/Rig/Mth</td>
<td>196</td>
<td>27</td>
<td>102</td>
</tr>
<tr>
<td>6.</td>
<td>Productivity RM/Rig/Mth</td>
<td>3827</td>
<td>485</td>
<td>1833</td>
</tr>
<tr>
<td>7.</td>
<td>Piling Crew/Rig/Shift</td>
<td>5</td>
<td>16</td>
<td>9</td>
</tr>
</tbody>
</table>
6.5 Hydraulic Pile Head Breakers to Eliminate the Slow and Laborious Manual Breaking of Pile Heads (Fig. 4)
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. The method employed in our country is manual labour with hammer and chisel or jack hammers. With projects size and corresponding pile numbers increasing significantly in recent years the above methods were found to be time consuming. Hydraulic pile breakers hung from and powered by excavators to crush concrete of square and round piles were introduced at RIL Kakinada and IOCL Panipat project sites. 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.

6.6 Hydraulic Rotary Piling to Install Bored Piles through Tough Fill Materials such as Slag
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. With the current large scale expansion of steel industry fresh units are being set up in these filled up areas. Because of heavy loads and sensitivity to differential settlements the plant structures and equipment are generally supported on bored cast-in-situ piles. Conventional tripod-winch-chisel/bailer type of boring has been in use for several years. Hydraulic rotary piling rigs have been introduced after careful trials and are found to increase productivity significantly. Currently in a project at SAIL, Burnpur, India more than 35000 bored piles of 550 mm diameters and around 20 m length are being installed with both rotary piling rigs and conventional tripod rigs. 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. Temporary casings are being used to stabilize the walls of the pile bore.

6.7 Special Polymer to Stabilize Walls of Pile Bore in Slag
As mentioned above temporary or permanent steel liners are being used to stabilize the walls of the slag fill in the steel industry. This method slows down the boring rate. 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 resulting in 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.

6.8 Side Grip Vibro-cum-Impact Hammer System to Accelerate Sheet Pile Installation and Extraction (Fig. 5)
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. Drop hammer, impact hammers and modern hydraulic or electrical type vibrohammers are being employed. Because of the above mentioned reasons the sequence of sheet piling and excavation also suffers some setback leading to difficulties in driving to required depths and at times leads to collapse of the walls of excavation. Wider application of sheet piling by making available the sheet pile materials and installation equipment would benefit the construction industry immensely. Side grip vibrohammer together with reversible type impact hammer was imported from Finland. 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.

6.9 Trench Cutter to Install Dam Cut-off Walls (Fig. 6)
Dam cut-off walls are being installed in India with the help of Reverse Circulation Rigs of old designs. National Hydroelectric Power Corporation (NHPC) changed this trend by making it mandatory to employ the state-of-the-art Hydromill/Trench Cutter equipment. These equipments bring speed and quality to the cut-off wall construction. 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.
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6.10 Automation for Data Logging and Pile Installation Monitoring Systems (Fig. 7)

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. 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.

6.11 Vibro-Compaction for Structures on Slag Fill

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. Vibrocompaction trials were carried out in the heterogeneous slag fill. 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. These trials if accepted by client and consultant would pave the way to minimize or altogether eliminate the necessity to support structures on piles.

6.12 Embedded Load Cells in Land Piling Jobs for Pile Load Tests

For piles with large load carrying capacity it is very risky and cumbersome to carry out static load test using the conventional Kentledge or pile/anchor reaction systems. Osterberg Cells (“O-Cells”) are becoming very popular throughout the world for their simplicity and reliability. One such test is being introduced at one of the prestigious projects in the national capital. In this system a load cell is placed at a pre-determined location within the pile and strain gauges are fixed at a numbers of locations along the length of the pile. Using a hydraulic pressure system the load cell is energized taking reaction from both segments of piles. Load settlement data of both segments of the pile are monitored besides load distribution along the length of pile. Such tests should be made popular as they would give reliable information and at the same time are faster, easier and safer to conduct compared to conventional pile load tests.

7. PROPOSED FOUNDATION TECHNOLOGIES

Based on study of various foundation technologies and the potential for wider application in our country the following foundation technologies are proposed by the author:

(a) 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
(b) Driven cast-in Situ Piling with integrated piling rigs equipped with energy efficient impact hammers, casing extraction systems and data logging and monitoring systems
(c) Sheet Piling
(d) CFA Piling
(e) Deep Soil Mixing
(f) Jet Grouting
(g) Rapid Impact Compaction
(h) Mass Stabilization with automatic dosing, mixing and monitoring systems
(i) Hydraulic Pile Head Breakers
(j) Screw Piles/Helical piles
(k) Self Compacting Concrete
(l) Ground Improvement with Vibro-Compaction/Vibro- Replacement
(m) Diaphragm walls with Kelly/Mechanical/Hydraulic grabs/Trench Cutter or equivalent, with Slurry Handling/Separation Systems, Concrete Batching Plant,
8. SUGGESTIONS

(a) With various announcements by the government for rapid development of India’s rural and urban infrastructure, power, housing, etc., it is expected that there will be tremendous pressure on Construction Industry for speedy and quality construction. Obviously the foundation engineering industry would also be impacted and there is a need to review the current practices and upgrade them to match the demand. Since there are several technologies, equipment, materials and methods already developed in the advanced countries a national level forum comprising of government, industry and academia needs to be formed to study and prepare a document of what technologies, equipments and methods we need for our country. Government bodies, premier institutes of research and major construction companies and consultancy firms should collectively address this issue and pave way for bringing these technologies and equipment within a short time frame. Indian Geotechnical Society can play a key role in this task.

(b) There should be a separate fund to import select technologies, equipment and materials and to conduct field trials to demonstrate their suitability. Task force teams should be formed for each technology and they should be responsible to carry out trials, to make specifications and to frame guidelines for consultants and contractors to follow in India.

(c) Government initiative is essential to encourage manufacturing of special foundation equipment in India in collaboration with reputed foreign firms so that these equipment are available at affordable prices.

(d) Government aided training institutes should be formed to develop special skills required to operate the equipment and to supervise the special foundation works. Since expertise in foundation equipment operation and supervision for quality and speed cannot be developed over night and the staff can only mature with time such training and continuous assessment of special skills can help in shortening the process.

(e) Because of the very nature of soil and rock a few alternative foundation solutions are possible for every structure. It is therefore important that alternative foundation systems are encouraged in every project by suitably modifying the tender specifications and contract conditions. Performance based contracts would encourage professionalism and competition to propose best possible alternative. Observational Method should become a part of every important foundation projects.

All the above should take place within a set time frame so that implementation can be shortened leading to streamlining application to projects. This will go a long way in accelerating the construction of various projects.

ACKNOWLEDGEMENTS

The author is grateful to the management of Larsen & Toubro Ltd for giving him an opportunity to introduce some of the latest foundation technologies, equipment and processes in their projects. He is also very grateful to his colleagues in the foundation engineering department who have been instrumental in implementing them with enthusiasm, passion and commitment and ensuring successful execution of critical foundation projects.

REFERENCES


