

Workshop on Deep Foundations (Well/Piles) for Bridges –Optimal Solutions

Central Road Research Institute, New Delhi organized a two days Workshop on Deep Foundations (Well/Piles) for Bridges-Optimal Solutions during 29-30th November 2006. The Workshop was well attended by about 150 delegates from various parts of the country. The proceeding of the Workshop consisted twenty papers – eight key note addresses and twelve invited papers from academicians, researchers, bridge designers and construction agencies. The Workshop was sponsored by five organizations – Border Roads Organisation, New Delhi Central Building Research Institute, Roorkee, Structural Engineering Research Centre, Chennai, Intercontinental Consultants & Technocrats Pvt Ltd., New Delhi and Span Consultants, New Delhi and co- sponsored four organizations namely - Grasim Industries, New Delhi, Ultra Technologies Pvt Ltd, New Delhi, Consulting Engineering Services (India) Ltd., New Delhi and AIMIL, New Delhi and supported by two organizations- Maccaferri Environmental Solutions Pvt.Ltd, Navi Mumbai and M/s Ground Engineering Ltd, New Delhi.

The Workshop was inaugurated by Prof. D.N. Trikha, Former Director SERC, Ghaziabad and Head, Dept. of Civil Engineering, University of Roorke on 29th November 2005. The concluding session comprised of a panel discussion and was chaired by Sri. A. Chakraborti, Director General, CPWD, New Delhi.

During the five technical sessions on the themes namely Innovation in Planning Analysis & design of Bridge Foundations, Economics of Well Foundations Vs Pile Foundations for Bridges, Behaviour of Foundations under earthquake generated Forces and New Construction techniques, eight key note addresses and ten invited papers were presented by eminent bridge designers, owners, academicians and researchers.

The summary of various sessions held during the workshop is given below.

Inaugural Session

Dr. P.K. Nanda delivered the welcome address at the inaugural session. He expressed concern about increasing depth of foundation for newly constructed bridges.

Dr. Ram Kumar, Head Bridges Division explained the genesis of workshop theme and about the technical papers included in the five sessions.

Prof. Trikha in his inaugural address stressed the need to develop knowhow for distress diagnosis in foundations, NDT techniques and techniques for repair and rehabilitation of foundations and instrumentation for monitoring the performance of bridge foundations.

This session concluded with the Vote of Thanks proposed by Sri. Sudhir Mathur, Head, Geotechnical Engineering, CRRI.

Technical Session –I on the Theme - Innovation in Planning, Analysis & Design of Bridge Foundations

This technical session was Chaired by Sri. P.L. Bongirwar, Adviser, L&T, Mumbai and Convenor, Foundation Committee, IRC and Co- chaired by Sri. V.K. Sinha, Secretary General IRC and included three key note presentations.

Sri. V. N. Heggade in his keynote address demonstrated with examples that small innovations in construction techniques of deep foundations can lead to qualitative and economical construction, like jack down method of well sinking in which it is possible to reduce steining thickness as sinking is achieved by application of external prestressing equivalent to reduced steining thickness in quantum. He explained soil structure interaction for piled raft as well as computation of spring constants for design of pile foundation. He explained that though Bored Precast piles can be conveniently used for land based flyovers, they have not found in place in IS: 2911 as well as in IRC: 78-2000. As bridge foundations are generally susceptible to Sulphate and chloride attack, durability is a very important aspect which needs to be considered during design. Foundations are provided with 75mm cover and coarse aggregate forms about 50% weight of concrete. Therefore, in bridge foundation construction, use of 40mm down aggregate and partial replacement of Ordinary Portland Cement (OPC) by mineral admixture like fly ash, Ground granulated blast furnace slag and so on should be recommended from economy, durability and sustainability consideration.

Sri T. Viswanathan in his keynote address brought out the possible innovations in planning, analysis, as well as design of open, pile and well foundation for bridges with examples. While selecting the type of bridge foundation, bridge span, bridge type, scour expected, stream velocity, available construction time, soil characteristics, and so on needs to be considered. He illustrated that only of well foundation is suitable at bridge sites with artesian condition. He pointed out that after the revision of seismic clauses for bridges in IRC:6 in 2000, the cost of foundation has tremendously increased. This is due to the working stress method adopted for design of bridges. Therefore, he stressed the immediate need to look into the load combination and load factors to be used for bridges including foundation design in limit state method.

Prof. S.K. Thakkar in his keynote paper explained the behaviour of well foundation under earthquake generated forces. He stated that well/caisson foundations have performed well during moderate earthquakes up to magnitude 7. He presented few cases of bridge collapse due to failure of foundation in large earthquakes mainly due to liquefaction of surrounding soil strata, lateral spreading of soil, loss of foundation bearing capacity and also due to tilting and settlement of well, cracking in well-cap and steining. He explained that soil structure interaction is not important in the case of open foundation where as it is very important in stiff structure like well foundation founded in soft soil. Inclusion of soil structure interaction in the analysis will help to reduce the natural frequency or increase the time period. Therefore, he stressed the need for suitable mathematical modeling of foundations and soil following rational methodology to determine earthquake effects on well foundations. He further emphasized the need for a well defined seismic design philosophy of foundations, such that its behaviour remains elastic under severe seismic conditions as it is difficult to repair foundations. Seismic philosophy for foundation

design should aim at effectively limiting the load transferred to foundation by allowing the formation of plastic hinge in pier. As well foundations do not enter the plastic range, under design seismic action no special detailing is required. He pointed out the need for R&D by experimental and numerical methods to consider various aspects of soil structure interaction of bridge foundation as well as measurement of structural response of well foundation in earthquakes to quantify its performance.

After the presentations, floor was open for discussion and at the end Chairman summarized the proceedings of the session.

Technical Sessions II on the Theme - Economics of Well Foundations Vs Pile Foundations for Bridges

This session was chaired by Sri. R.R. Jaruhar, Member (Engineering) Railway Board and Co-chaired by Prof. D. N. Trikha and two key note papers and two invited papers were presented.

Sri.P.L. Bongirwar made a detailed comparison of well and pile foundation construction for bridges and flyovers. Though well foundation requires only convention equipments for construction, pile foundation needs sophisticated equipments for construction as well as testing. He emphasized that in Mumbai, it was possible to complete construction of 44 flyovers in a short span of four and a half years only due to the adoption of pile foundation for flyovers. He illustrated the application of pile foundation in Konkan Railway, Bandra-Worli Sea Link and so on as well.

Prof. M.R. Madhav demonstrated the application of Geosynthetics Reinforced Soil (GRS) abutments for bridges with examples, which leads to complete elimination of either pile or well foundation. Further he clarified that GRS abutments behave well under earthquake forces as well. They are useful in soil with bearing capacity of about 900kPa, with well graded and well compacted granular backfill along with closely placed geogrids. The acceptable limit of vertical settlement is less than 100mm and lateral displacement is less than 50mm. Further, it is possible to reduce settlements by a factor of two to six times by preloading.

Sri. Subodh Kumar Jain stressed on the fact that techno-economics of deep foundation depend on depth of foundation, number of span, sub soil conditions etc. He explained the foundation construction practices adopted by Indian Railways for their bridges. He felt that though with the help of pile foundation, the construction is much faster, but there are certain maintenance requirements of this type of foundation. Pile foundation especially with steel liner is susceptible to corrosion.

Sri. S.P. Joglekar presented the design details including aseismic design features of Orsang aqueduct as one of the pioneering applications of pile foundation for piers in our country, in which more conventional well foundations were replaced by piles.

After the presentations, floor was open for discussion and at the end Dr. Trikha summarized the proceedings of the session.

Technical Sessions III on the Theme - Economics of Well Foundations Vs Pile Foundations for Bridges

In this technical session three papers were presented and was chaired by Sri. S.G. Joglekar, Director (Engineering Core), Stup Consultants Mumbai and Co- chaired by Sri. Subodh Kumar Jain, Principal Chief Engineer, Central Railway, Mumbai.

Sri. S.A . Reddi, with examples of existing bridges emphasized that worldwide there is an increasing trend for adopting piles for bridge foundations. Typical Indian bridges cost about 40% more than bridges being constructed in US and Europe. Main reason for higher cost is the time and overruns in Indian Scenario due to uncertainty associated with the well foundation mainly adopted for river bridges. Pile foundations on the other hand require lesser time for construction. He explained that presently the larger diameter piles being adopted in the construction of bridges in urban areas and they are reaching the dividing line between piles and small wells. At present State –of-the –Art equipments and hydraulic rigs are adequately available for pile installation in our country. Pile foundations are economical for bridges with total span more than 200m. He further stressed the need to effectively utilize the resources available in the country for bridge construction.

Sri. V.K. Agnihotri emphasized that well and pile foundation is not to be viewed as competing technologies but as complementing techniques for bridge foundation. He discussed the key parameters for economic design of deep foundation such as span configuration, founding level below HFL, flood data collection, scour depth, advanced soil investigation techniques and so on. He stresses that scour depth calculation in Indian Codes of Practice is Lacy-English Formula, meant for non-cohesive sandy material. However, no provision is available in codes for clayey or gravel bed rivers. Also, the latest trend is to build the new bridges with lower founding levels than the old existing bridges. Therefore, there is an urgent need to review the codal provision with respect to scour depth. Also, it is possible to reduce scour by adopting slots or collar. Therefore, government organizations should undertake research and developmental works in evaluation of design parameters like scour.

Sri. D.D. Sharma presented a detailed case study of relative economics in adopting pile and well foundation for abutment of a bridge with 16.5m span and height varying from 4.7 to 10.3m. He expressed concern about the clause 709.1.7 of IRC: 78 (2000), which stipulates minimum diameter of bored pile as 1.0m and 1.2m in bridges on land and river, irrespective of span or height of bridge. Also, the clause 709.1.9 stipulates minimum grade of concrete as M35. These clauses have serious implication in cost and feasibility of pile foundation with respect to corresponding clauses of IS: 2911. He also explained that the embedment length of pile increases drastically as per existing IRC: 78 in comparison to the older version. However, economic analysis clearly indicated that the selection of diameter of pile should be left to the designer and by specifying the diameter in the code, the pile capacity is under utilized. Therefore, urged IRC to review these clauses for arriving at rational design of pile and pile caps.

After the presentations, floor was open for discussion and at the end Sri. Subodh Kumar Jain summarized the proceedings of the session.

Technical Session IV on the Theme -Behaviour of Foundation under Earthquake Generated Forces

This session was Chaired by Sri. V.K. Agnihotri, Director LEA Associates, New Delhi and Former Member (Engineering), Railway Board and Co-chaired by Sri. T. Viswanathan, Vice President, Aarvee Associates, New Delhi and one key note presentation and two papers were presented in this session.

Prof. Sudhir Jain in his key note presentations made a comparison the seismic forces on bridges by IRC:66-1966 and IRC:6 :2000. As per IRC: 6, the inertia force on buried portion of well foundation need not be considered, whereas this is in contradiction to IS: 1893. He discussed application of different mathematical model with a case study for analysis of foundation system and brought out that inertia of soil plays an important role in seismic response of bridges. Further, if spatial variation is ignored, earthquake forces reduce considerable.

Prof. D.K. Paul in his paper brought out that Integral bridges are more appropriate for small and medium span bridges in seismically active zones. He illustrated that damages in many bridges have occurred mainly in bearings and expansion joints. IS: 2911 code restricts the top lateral deflection of pile to 5mm, which results in restricting the length of integral bridge.

Dr. Lakshmy Parameswaran stressed the need for development of guidelines for new pile construction using screw pile, piled raft, continuous flight auger, and micropiling and so on for their application not only for new bridge foundations but also for widening and seismic retrofitting of bridges.

After the presentations, floor was open for discussion and at the end Chairman summarized the proceedings of the session.

Technical Session V on the Theme - New Construction Techniques

The Technical Session was chaired by Prof. V.S. Raju, Chairman Research Council, CRRRI and Former Director, IIT Delhi and Co-chaired by Sri. S.A Reddy, Adviser, Gammon India Ltd, Mumbai and included one key note address and two invited papers.

Sri. D. K. Kanhere brought out the fact that uncertainties in the pile design arise due to regional geology. Some areas of concern to Engineers for bored cast-in-situ piles socketed in rock, are socketing and its utility, unit socketing friction and unit end bearing resistance as well as elastic settlement of socketed piles. He explained the construction practices and testing methodology adopted for pile foundation in some of the Mumbai Flyovers. Large diameter bored piles are still relatively new in India. As pile load capacity increases it may be difficult to fabricate heavier hammers and design fall mechanisms. It may be practically not possible to conduct a static load test. Recently many countries have reported using the PDA to measure pile capacity up to 5000MT. As

far as testing of piles is concerned, high strain dynamic pile testing is fairly reliable to evaluate pile capacity. The method is faster than an equivalent static load test. Several piles could be dynamically tested in a day and it helps in verification of structural integrity as well.

Prof. S.R .Gandhi presented the design and construction aspects of well foundation for bridges.

Sri. Dhruvajyoti Bhattacharya, explained that in conventional “Tremie Technology”, as applied, in general, in cast-in-situ bored piles, as per clause 6.3.3 of IS:2911 (Part I / Sec 2), no extra cement is added. In IRC:78-1983 (1st rev), both ‘**Tremie Pipe**’ and ‘**Skip Box**’ were permitted for concrete under water in well bottom plug. Subsequently in IRC:78-2000, clause 708.8.2 states for well bottom plug the concrete shall be placed gently by *tremie boxes* under still water condition. However in view of improvement of bottom plug concrete quality and execution point of view, the MoRT&H specifications have been revised stipulating the only ‘**Tremie Pipe**’ method for well bottom plug. However, based on the analysis presented by him, the clause 708.8.2 of IRC:78-2000, requires further modification.

After the presentations, floor was open for discussion and at the end Chairman summarized the proceedings of the session.

Panel Discussion

Dr. Ram Kumar presented a brief summary of papers and discussions held in various technical sessions. The panel discussion was also on the same topic as theme of workshop. The following were the panelists:

Sri. A. Chakraborti
Sri. P.L. Bongirwar
Sri. S.P. Chakrabarti
Sri. V.K. Agnihorti
Sri. S.A. Reddi
Prof. V.S. Raju
Dr. P.K. Nanda

Sri. P.L. Bongirwar, Convenor, Foundation Committee welcomed suggestions from delegates regarding clauses of IRC: 78 (2000) that require amendments. He requested them to forward the same either to IRC or to him for review. He emphasized that adoption of new construction practice should precede preparation of guidelines.

Sri. S.P Chakrabarti felt that both well and pile foundation are complementing technologies for bridges.

Prof. V.S. Raju emphasized that bridge designers and construction engineers should welcome new practices for achieving economy in new bridge construction.

Sri. V.K. Agnihotri urged government agencies to sponsor research programmes in the area of scour of bridge foundations.

Dr. P.K. Nanda stated that both well and pile foundation construction practices will co-exist in the country. The recommendations of the workshop would be sent to Indian Roads Congress as well as Bureau of Indian Standards for making amendments in respective foundation codes.

Sri. S.A. Reddi urged the bridge engineers to adopt pile foundations for bridges and flyovers on account of its advantages over well foundations.

Sri. A. Chakraborti emphasized the need to review the existing seismic provisions for bridges as the bridge foundations are becoming costly. He felt that to meet the challenges of ongoing infrastructure development in the country, more sophisticated construction equipments are necessary.

After the panel discussion, the floor was open for discussion.

The session ended with a vote of thanks by Sri. Guru Vittal, Scientist, Geotechnical Engineering Division, CRRI.

Recommendations:

The recommendations of workshop are as follows:

1. Well and pile foundation is not to be viewed as competing technologies but as complementing techniques for bridge foundation.
2. Bored precast piles are useful for land based flyovers, and need to be included in IS: 2911 as well as IRC: 78:2000.
3. In bridge foundation construction, use of 40mm down aggregate and partial replacement of Ordinary Portland Cement (OPC) by mineral admixture like fly ash, Ground granulated blast furnace slag and so on should be recommended from economy, durability and sustainability consideration.
4. For rational design there is an immediate need to look into the load combination and load factors to be used for bridges including foundation design in limit state method.
5. Review the following clauses of IRC: 78(2000)- clause 719.1.7, 719.1.9 and make necessary amendments keeping in view the fact that the selection of diameter of pile should be left to the designer for rational design of pile and pile cap.
6. Clause 708.8.2 of IRC: 6 needs to be reviewed and modified appropriately.
7. Research and developmental work should be undertaken by government agencies in evaluation of design parameters like scour for design of bridge foundation in clayey and river with gravel beds.

8. Pile foundations are economical for bridges with total span more than 200m.
9. Application of GRS abutments in bridge construction needs to be encouraged in our country.
10. Innovative construction techniques need to be applied for both pile and well construction. Pile raft foundations are useful for flyovers.
11. Integral bridges are well suited for small to medium span bridges in seismically active areas.
12. There is a need to develop guidelines for new piling techniques like piled raft, Continuous flight auger, screw piling, micro piling and so on not only for their application in new construction but also for widening and seismic retrofitting of bridges.
13. There is need for R&D by experimental and numerical methods to consider various aspects of soil structure interaction of bridge foundation as well as measurement of structural response of well foundation in earthquakes to quantify its performance.
14. Clause 222.10 of IRC:6-200 needs to be reviewed with respect to IS:1893 and amended.