Managing Tunneling Induced Ground Movements

Tunneling in urban areas is complex, with changing ground conditions that can cause delays, higher costs, and damage to nearby structures. Real-time instrumentation and monitoring help manage these risks by enabling early detection of issues allowing for quick remedial actions to optimize design and improve safety. The LA Metro Crenshaw/LAX Corridor project illustrates the value of such monitoring, as it controlled ground movements and protected nearby infrastructure. This case shows that real-time monitoring is a valuable investment for successful urban tunneling projects. Read more in ***Page no. 3.***

Volume 10 Book 4, October 2024

DFI of INDIA News

Quarterly Newsletter from
Deep Foundations Institute of India
www.dfi-india.org

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DFI of INDIA News
Volume 10 Book 4, October 2024
3

Managing Tunneling Induced Ground Movements

Cover Story

Lucky Nagarajan, Director of Business Development, Consulting & Monitoring, Geocomp ; **W. Allen Marr,** Former CEO and Senior Strategic Advisor, Geocomp

Instrumentation and monitoring are crucial for ensuring safety, stability, and quality in tunneling projects. With tunnels and metro lines being constructed worldwide, it is essential for geotechnical engineers to understand the risks and ensure community safety. The LA Metro Crenshaw/LAX Corridor project demonstrates the value of real-time monitoring in minimizing ground movements and damage from urban tunneling.

The project, part of the Los Angeles County Metropolitan Transportation Authority's (Metro) expansion, includes 8 stations, cut-and-cover structures, and twin bored tunnels. This paper focuses on Underground Guideway #4 (Figure 1a), spanning 8,430 ft, with three underground stations: Expo, MLK, and Vernon. Ground movements discussed in this paper are along the alignment shown in Figure 1b.

The twin tunnels, with a centerline separation of 39.13 ft, were excavated using an EPB TBM with a 33-ft shield. The "overcut" dimensions increased from 0.6 inches behind the cutter head to 1 inch at the shield's back. The excavation diameter was 21.49 ft, with precast concrete rings of 18.83 ft I.D. and 5 ft length.

Figure 1. (a) Location of Underground Guideway #4, LAX/Crenshaw Rail Project; (b) Extent of Alignment of Interest and Select MPBX Locations

The tunnel axis depth ranged from 51.5–54.5 ft between Expo and MLK Stations and 41.5–61.5 ft between MLK and Vernon Stations. Performance limits for surface movements were 0.5 inches (action) and 0.6 inches (maximum), and for bottom anchor movement, 0.75 inches (action) and 1.5 inches (maximum), measured 5 ft above the tunnel crown (Adib et al., 2018).

Several initial challenges related to optimizing TBM control parameters were overcome. The low advance rate was resolved by adjusting TBM mining parameters, including foam injection and cutter head torque. Ground movements exceeded project performance limits, correlating with malfunctions in the TBM shield bentonite system (Chan et al., 2017). Although the 33-foot shield prevents significant caving, ground movement can occur in the overcut region if a pressurized "envelope" is not maintained (Cording, 2016). The TBM's bentonite injection system, designed to form a bentonite "cake" within gravelly material, required volumetric control matched to the advance rate and pressure limits (Dias and Bezunjian, 2015). Injection pressure was set close to the calculated face support pressure at the tunnel crown (Chan et al., 2017). Following bentonite injections, surface ground movement was typically 1⁄4 inch after each tunnel drive.

PROJECT BACKGROUND

Geological And Geotechnical Information:

The project is in the northern Los Angeles Basin, underlain by unconsolidated Quaternary alluvial sediments (Metro, 2012a), subdivided into Holocene-age Young Alluvium and late-Pleistocene Old Alluvium. The tunnels were excavated in the Old Alluvium.

The Young Alluvium, 30 ft thick, consists mainly of fines (silt, lean clay, and fat clay) with frequent organic clay strata. The upper 50 ft of the Old Alluvium (30–80 ft depth) comprises coarse sediment, including pebble-gravel and sand.

Continued

Groundwater was reported at 45–60 ft depth.

Geotechnical Instrumentation and Monitoring: Geocomp Corporation procured, installed, and monitored the geotechnical instrumentation system to track construction-induced movements and groundwater drawdown within the station and tunnel excavation zone. The system included manually and automatically monitored instruments, with data logged into Geocomp's cloud-based iSiteCentral® and linked to the TBM data management system to correlate ground movement with TBM position.

Subsurface movements were tracked using Multi-Position-Borehole Extensometers (MPBX) with grouted anchors. Each MPBX had three anchors with displacement transducers measuring relative movement between the anchor and MPBX head. Anchors were located 5 ft above the tunnel crown, 5 ft below the surface, and midway between. The MPBX head, housed in a well box and "de-bonded" for independent movement, was surface-protected. Surface movements were monitored using reference points (pk nails) and Feno-type anchors.

OBSERVED GROUND MOVEMENT

Deformations between Expo and Vernon stations: The ground movements discussed were measured during mining of the SB tunnel between Expo and Vernon stations. The MPBX locations are shown in Figure 1(b).

Figure 2 summarizes maximum absolute movements at the bottom anchor of each

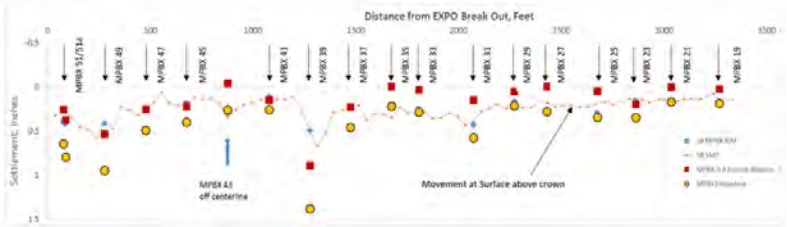

Figure 2. Measured ground movement between EXPO and MLK stations

MPBX, corresponding surface movements at nearby settlement points (SMPs), and at the MPBX road box rim, plotted against the distance from the tunnel start at Expo station.

Key observations from the data:

- Most relative movement at the bottom MPBX anchors occurred just above the TBM shield after the cutter-head passed.
- Ground movement, both at the surface and depth, decreased following the remedial measures.
- Relative movement at the bottom anchor of MPBX 39 exceeded the uniform maximum overcut thickness, supporting prior findings (Loganathan & Poulos, 1998; Pinto & Whittle, 2014) that the actual gap above the tunnel crown can surpass the overcut thickness.
- The reduction in ground movement at MPBX 39 after the TBM shield tail passed confirms that tail grout pressure can lift the ground, reducing settlement by approximately 0.5 inch.

Deformations at the MLK Station: Settlement monitoring points outside the station show unexpected heave instead of settlement. Figure 3 indicates up to 0.45 inches of heave at the surface, with over half the points consistently showing heave up to 220 ft from the excavation support system. Engineers had predicted up to 1 inch of settlement near the excavation.

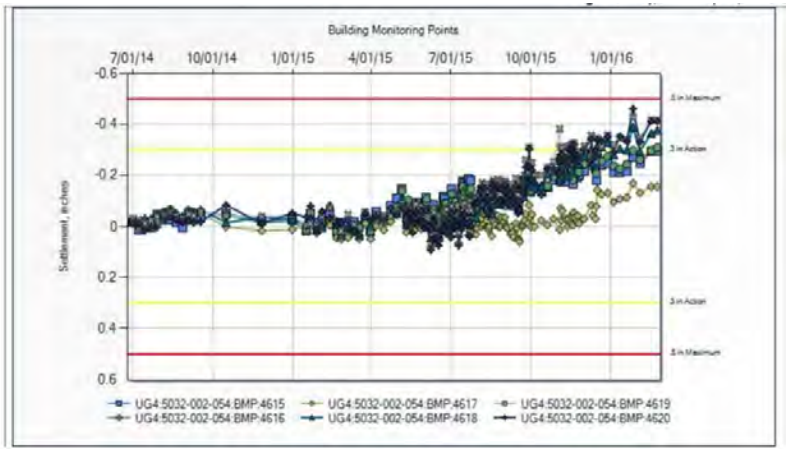

Figure 3. Heave measured at points 4615 through 4620 (points located along the northwest exterior face of the MLK station support) Continued on Page 15

DFI of India Support Committee Member Message

- Mr. Seth Vaidya

From Hyderabad to Goa, the Deep Foundations Institute of India (DFII) conferences have made remarkable strides over the past 13 years, marking a transformative journey. Reflecting on the winter of 2011, I recall my early-morning monthly calls with Dr. K. S. Ramakrishna, the founding father of DFII, Theresa Engler, the DFI Executive Director, and a conference manager from IQPC. These calls were dedicated to planning DFII's first international conference. At that time, there were no other local volunteers or organizing committee members participating in these calls.

Mr. Seth Vaidya

Principal / Vice President, Langan Engineering & Environmental Services

Fast forward to the present, as my rental car approached the wide gates of the Kala Academy in Panjim, I was greeted by a striking DFI-India 2024 conference banner adorned with the names of numerous prominent corporate sponsors and an army of volunteers. This was a far cry from the modest beginnings at the Novotel Hyderabad airport in 2011. Upon arriving, the next thing that caught my eye was a large banner at the main entrance featuring a photograph of the Chief Minister of Goa, Dr. Pramod Sawant, who was announced as the conference's Chief Guest. This was a significant achievement for DFII and a pleasant surprise.

The reception area was efficiently managed, and I quickly received my conference kit and badge. The exhibit area was bustling with energy, featuring nearly 30 exhibitor stalls, and the atmosphere in the main auditorium was equally vibrant, with over 350 delegates in attendance for the inaugural session. The conference began with an inspiring inauguration by Dr. Omprakash Jaiswal, Director of NIT Goa, in the distinguished presence of several prominent figures. Among them was Prof. Madhav Madhira, who received the DFI of India's Lifetime Contribution Award. The event was further graced by the presence of the

Continued

honorable Chief Minister, who inaugurated the exhibit hall and also launched a book authored by the conference chair, Prof. Purnanand Savoikar. The other noteworthy event on the second day was the session hosted by the Women in Deep Foundations (WiDF), featuring Mrs. Odette Da Silva, the first female Chief Engineer of the Goa Public Works Department since the state's liberation, as the honored guest speaker.

The afternoon of Day 1 and the following one and a half days were packed with stimulating technical content, including seven keynote lectures, a special session on foundations for tall buildings, 46 paper presentations across three parallel tracks, and 28 poster presentations. The keynote speakers were industry stalwarts Dr. Venu Raju, Mr. Uday Veer Singh, Prof. Madhav Madhira, Mr. Thomas Domanski, Prof. Alessandro Mandolini, Mr. Allen Marr, my good friend and DFI of India Support Committee co-chair Lucky Nagarajan, and Dr. C. R. Parthasarathy. I personally enjoyed the distinct honor of joining esteemed expert speakers like Prof. Mandolini, Prof. Deepankar Choudhury, Mr. Hamzah (on behalf of Dr. Marwan Alzayaie), and Mr. Robert Dunaevskiy on the special session panel for foundations for tall buildings.

Every session was meticulously organized and executed with great attention to detail. Even the tea, snack, and lunch areas were well-managed, offering attendees a delightful array of sumptuous food, including local Goan favorites. The second day concluded with a fantastic local dance program, followed by a cocktail hour and a dinner banquet. Although I missed the fun myself, I heard rave reviews about the fabulous dance party that followed the banquet.

The DFII staff, including Pranav Jha, TS Mahendran, and Sai Sindhu, along with their dedicated cohort of student volunteers from Goa Engineering College, Don Bosco College of Engineering, and BITS Goa, put on an outstanding show. I have immense admiration for their hard work and dedication. As the conference drew to a close, I could see the pride in the eyes of DFII leaders Mr. Mohan Ramanathan, Anirudhen IV, and Dr. Sunil Basarkar. On behalf of the DFI of India Support Committee, I extend my heartfelt thanks to all the organizers, volunteers, speakers, exhibitors, and participants for making this conference a resounding success.

DFI of India Life Time Contribution Award 2024

Every year, DFI of India recognizes a distinguished senior professional in the field of Deep Foundations for their substantial contributions and lifelong dedication to a meaningful cause, profession, or initiative. This recognition highlights the recipient's steadfast commitment, enduring dedication, and significant influence in the field. This year, we are pleased to honor Prof**. Madhav Madhira,** former Professor at IIT Kanpur, Visiting Professor at IIT Hyderabad and Professor Emeritus, JNTU, Hyderabad.

Born in 1940, **Prof. Madhav** graduated in 1960 in Civil Engineering with fi rst-class Honours from Andhra University, Visakhapatnam. He completed his M.E. with Distinction in Soil Mechanics and Foundation Engineering from the Indian Institute of Science, Bangalore, in 1962. He obtained his doctorate in 1967 from the same institute, for his work on consolidation of clays. Prof. Madhav earned a DSc in Modelling and Analysis in Geotechnical/Ground Engineering from the Indian Institute of Science, Bangalore, in 1999. He currently is a Distinguished Visiting Professor at AICTE-INAE, a Visiting Professor at I.I.T., Hyderabad, a Professor Emeritus at J.N.T.U, Hyderabad, a Resource Person at Rajiv Gandhi University of Knowledge Technology, and a Guest Faculty at Engineering Staff College. Prof. Madhav had a long, illustrious academic career at I.I.T. Kanpur and retired as a Professor of Civil Engineering in 2003. Prof. Madhav served at several other universities abroad and was Formerly the Chairman of the Research Council, CSIR-CRRI. Prof. Madhav's research interests spanned the whole gamut of Geotechnical Engineering and established an imprint on modeling and numerical analysis. He guided more than 45 doctoral and several master's theses and final-year projects. He co- edited books entitled 'Lowlands - Development and Management' and 'Foundations and Soft Ground Engineering Challenges in Mekong Delta'. He authored over 550 publications in referred international and national journals and conferences. He made more than 150 special presentations on geotechnical engineering topics. . Prof. Madhav continues to be active in the geotechnical consultancy for complex foundation solutions and ardently advocates for sustainable foundation solutions, monitoring the performance of geo-structures and measuring the response of ground.

Technical articles / presentations of relevance are invited from the readers.
Please prepare the document in MS word format along with good quality figures and pictures

Recap - DFI-India 2024: 13th Annual Conference

The DFI-India 2024: 13th Annual Conference was successfully held during September 19-21, 2024, in the picturesque coastal city of Goa. Following the success of the previous conference in 2023 in Vadodara, this year's event once again served as a pivotal platform for industry professionals, engineers, and researchers to come together and exchange ideas on the latest advancements in deep foundation technologies for infrastructure development. IGS Goa chapter was the conference co-organizer and the chapter chair, Prof. Purnanand Savoikar chaired the conference. The event was co-led by the Technical Chairs, Dr. Sunil S. Basarkar and Dr. Jaykumar Shukla, whose leadership ensured that the technical content was of the highest caliber.

The Conference garnered exceptional support from the industry through sponsorships and exhibitions, with over 350 delegates from various organizations in attendance.

The event commenced with the inaugural ceremony graced by the Chief Guest, the Hon'ble Chief Minister of Goa, Dr. Pramod P. Sawant, and the Guest of Honour, Dr. O. R. Jaiswal, Director of NIT Goa. Their presence underscored the growing importance of deep foundation engineering in the infrastructural development of the region.

Prof. Madhav Madhira, was honored with the Lifetime Contribution Award 2024. The Exhibition was inaugurated by the Chief Guest, Dr. Pramod P. Sawant.

Keynote Presentations

One of the standout features of the conference was the distinguished lineup of keynote speakers, representing both academia and industry.

Keynote 1: **Dr. Venu Raju** - *Sustainability in Geotechnical Construction – A Global and Indian View*
Keynote 2: **Mr. Udai Veer Singh** - *Experience with Construction of Deep Raker Piles for Volta Bridge Project in Ghana*
Keynote 3: **Prof. Madhav Madhira** - *Evaluation of Ground – Pile Interactions from Pile Load Tests*
Keynote 4: **Thomas Domanski** - *Advancement in Ground Improvement Techniques for the Construction of Load Supporting Columns in Soft Soils*
Keynote 5: **Prof. Alessandro Mandolini** - *A novel, simple but effective method for assessing pile base resistance in sandy soils*
Keynote 6: **Allen Marrr (Online)/Srilakshmi Nagarajan** - *Ground settlements from construction of the tunnels for the Crenshaw/LAX Transit Corridor Project*
Keynote 7: **Dr. CR Parthasarathy** - *Failure analysis, Design & Installation of Offshore Conductor Piles – Case Studies*

Continued

Technical photo feature of relevance are invited from the readers. The feature shall preferably illustrate a modern technology or testing procedure. Please prepare the feature with six to eight good quality pictures with brief and crisp description.

Special Session on 'Foundations for Tall Buildings'

The conference highlight was the special session on 'Foundations for Tall Buildings', an area that has seen significant advancements in recent years, particularly with the rise of megastructures in urban centers. The session featured Prof. Alessandro Mandolini, who discussed Piled Raft Approach to Foundation Design, Prof. Deepankar Choudhury, who presented on Geotechnical Investigations and Challenges in Foundation Design for Tall Buildings - Indian Perspective, Mr. Satyajit Vaidya, who shared about Rock-socketed Piles in the New York City, Dipl.-Ing. Robert Dunaevskiy, who gave insights on Contribution to Reduction of CO2-Emissions by Applying Economic CPRF Solutions for High-Rise Buildings and Mr. Hamzah M. B. presented on behalf of Dr. Marwan Alzaylaie, on Optimizing Deep Foundation Systems for High-Rise Buildings on Dubai Sedimentary Rock: Advances and Insights. This session was particularly well-received by practitioners and researchers, given the increasing demand for efficient and sustainable foundation solutions in high-rise construction in India's urban centers.

Technical Sessions and Paper Presentations

Over the course of the three-day conference, a series of technical sessions were held, covering a wide range of topics. These sessions featured over 74 paper presentations including poster and paper presentations, showcasing original research, innovative practices, and case studies.

Women in Deep Foundations India (WiDFI) Session

The WiDF India committee conducted an empowering session in the recent DFI-India 2024 Conference featuring Ms. Odette Da Silva, the first lady Chief Engineer of the Goa Public Works Department. By addressing both accomplishments and obstacles, Ms. Da Silva inspired attendees to support a more inclusive, dynamic future for the industry, resonating strongly with participants and reinforcing the mission of WiDF in India. The session was moderated by Ms. Lucky Nagarajan.

DFII Student Awards 2024

The Every year DFI of India conducts Student Awards Competition to encourage young talent to continue pursuing excellence in their research and professional development. The winners of the competition are Yogesh R V, Senior research fellow, CSIR- CBRI, Roorkee, Sougata Mukherjee, Research Associate, Indian Institute of Science, Bengaluru and Hadiya

Continued

Hardik Harilalbhai, Masters Student, IIT Bombay.

The winners were awarded with certificate, cash prize of INR 15,000 (sponsored by CECONS Pvt. Ltd), e-book vouchers by Springer, and free conference registration.



DFII 2024 Best Paper Awards

The Conference technical chairs selected two best papers among the 79 contributory papers. They are ***1) Ground Improvement Requirement for TBM Launching under Shallow Overburden in Close Proximity to Sea Shore,*** by Tanumaya Mitra, Sudip Kumar Koley, Padma Tiruvengala, Naru Raju, Prodyot Kumar Ray and ***2) Enhancing Tank Reliability: Performance Evaluation of Distressed Foundation Systems - A Case Study*** by Sampat Raj, Mriganabh Choudhury, VK Panwar, Sanjoy Bhowmik. The Winners received a certificate, and cash prize of INR 5,000.


The DFI-India 2024 Conference concluded with a renewed commitment to innovation, sustainability, and inclusivity within the deep foundations industry. Attendees left inspired, ready to apply new insights and foster stronger connections across the geotechnical community in India and beyond. We extend our heartfelt gratitude to all the supporters of DFI-India 2024, whose generosity and commitment made this event possible.

*To access the Conference Photos, **click here.***

DFI-India 2024: Photo Competition Winners

Ground Improvement in Kingstown's Port Modernization in Saint Vincent and the Grenadines

Mr. Jeevan Beela

Van Oord

Ground Improvement by Installation of PVD at JNPT Areain Mumbai

Mr. Jalinder Salunke

S&R Geotechniques Pvt. Ltd.

Honorable Mention - Photo Competition

Wicks Rapid Impact Compaction
Mr. Guido Freitag
Van Oord

The DFI-India Lifetime Contribution Award 2024 recipient **Prof. Madhav Madhira** shares his experience about "*Consequences of Ignoring Overconsolidation and its Effects on Settlement*" as a part of Geosutra 7 to be published in upcoming IGS newsletter where he talks about myth of soil being normally consolidated.

The article discusses the overconsolidation of soil deposits, particularly in the Indian subcontinent, challenging the belief that it is primarily due to unloading. Instead, factors such as long-term creep, desiccation, fluctuating groundwater levels, and chemical changes contribute to what the authors call "pseudo-overconsolidation." These factors result in soil properties similar to overconsolidated soils without a history of unloading, leading to inflated overconsolidation ratios (OCR).

Geotechnical practices in India often assume these soils to be normally consolidated, which can result in overestimating settlements by 100% to 500%, prompting unnecessary and costly ground improvement measures. The authors recommend more accurate methods, like Schmertmann's True In Situ (TIS) curve and the approach by Nagaraj et al., to account for pseudo-overconsolidated characteristics. These methods would enable more realistic settlement predictions, better aligning with the actual in situ conditions of Indian soils, thus enhancing cost-efficiency and accuracy in geotechnical design.

Access the article here: https://www.igs.org.in/storage/newsletter/IGS-News-July-Sept-2024-221124011552.pdf

DFI of India is happy to announce a new webinar series titled 'Practices for Efficient Subsurface Characterization' under the DFII Committee for Geotechnical Characterization for Foundation, designed to address the critical aspects of subsoil investigation and characterization which are fundamental to the success of any construction project involving deep foundations. The committee successfully conducted two webinars under this series starting from August 30 2024. The speaker being **Dr. CR Parthasarathy**, Founder, Chairman and Managing Director, Sarathy Geotech & Engineering Services Pvt Ltd. He presented on the topic ***'Case studies on Problems, Challenges and Solutions to Site Characterisation'***

The second webinar was conducted on Tuesday, 14 Nov 2024 from 5-6 pm IST. The speaker in this webinar is **Mr. Sorabh Gupta,** Director, Cengrs Geotechnica Pvt. Ltd. He spoke on the topic ***"Gold-Level Geotechnics for High-Rise Buildings".***

Watch the webinar recordings here:

https://youtube.com/playlist?list=PLp1slBNqY6TmlL4Tqf1EXheeN7puJXV1N&si=9I9383z98yzFbqa3

DFII & DFI Upcoming Events

Event	DFI of India Groundwork webinar series 2025	Conference on Foundation Decarbonization and Re-Use	SuperPile '25	DFI50
Date	Starting Jan 2025	March 25 - 27, 2025	June 18 - 20, 2025	Oct 20-23, 2025
Venue	Online	Amsterdam, the Netherlands	Cleveland, OH	Nashville, TN

Not a Member?
Join DFI here https://dfi.org/members/

DFII Technical Committee News & Reports

DFII Committee for Geotechnical Characterisation for Foundations

DCGCF committee conducted first 5-days workshop of 2024 (sixth overall) for Geotechnical Investigation laboratory Testing, at L&T Construction Research and Testing Centre, Chennai during 08 - 12 Jan'24. The program received excellent feedback from all the participants who joined the program from all across India. More workshops are planned in different regions of India.

The committee conducted the first webinar in the series "Practices for Efficient Subsurface Characterization" to address the critical aspects of subsoil investigation and characterization, which are fundamental to the success of any construction project involving deep foundations. The second webinar is successfully conducted on 14 Nov'24. More details in page no. 13.

DFII Training Committee on Foundation Technologies

After huge success of two training programs on Support Fluids for Foundation Construction and Tremie Concrete for Deep Foundations in 2023, DFII Training Committee conducted its fifth training program on 'Ground Improvement for Foundation construction' on 18 May 2024. It was a full day hybrid workshop conducted in-person at Raj Park Hotel, Chennai and online via zoom webinar. Leading experts from industry and academia participated and presented during the event. The workshop was sponsored by Bauer Engineering India Pvt. Ltd.

The program was attended by 46 in-person attendees and 40 online attendees. The technical coverage and insights provided by the experts got highly encouraging feedback.

The Committee is also planning to have more training programs on different topics like D-Walls, Working Platforms, Tool Management for Construction Equipment, etc.

DFII Student Outreach Committee-Groundwork

DFII Student Outreach Committee conducted three Groundwork online webinar series for 2024 in Jan, March, and July 2024. The winners of the Student Awards 2024 Competition, under this committee are awarded during the DFI-India 2024 Conference in Goa.

CFA Pile Technology Implementation Committee

The committee successfully conducted a workshop on CFA Pile construction in collaboration with IGS Kolkata Chapter on 30 March 2024. Several national and international experts namely, Er. Shyamal Kumar Mitra, Geotechnical Consultant, Dr. Martin Larisch, Director, Larisch Consulting Ltd., Mr. Prathmesh Wani, Geotech Engineer, Menard & Mr. Ian White, Business Unit Manager, Menard Middle East, Mr. Anirudhan IV, Geotechnical Consultant, and, Dr. Sunil S. Basarkar, Vice President, AFCONS presented during the program. It received excellent feedback from the participants. The program was attended by more than 250 online delegates.

The P20 sub-committee under CED 43 is ready with the draft of the BIS code for CFA Guidelines and reviewing the same. The guidelines document is expected to be out by this year end.

Women in Deep Foundations India

WiDF India Committee conducted a session in the DFI-India 2024 Conference featuring Ms. Odetta Da Silva, the first women chief engineer of PWD, Goa. The session was very empowering and well appreciated by the conference attendees.

Follow DFI of India on social media for updates & announcements

Continued from Page 4

INTERPRETATION

Interpretation of Deformations between Expo and Vernon stations: After implementing the improved bentonite injection and control system, the bottom anchor movement in the southern set was significantly reduced, even less than the surface movement near the MPBX location. In contrast, the northern set showed bottom anchor movement equal to or greater than the surface movement. Literature from the Seattle North Link and University Link projects (Salvati et al., 2016) indicates that in EPB TBM operations, bottom anchor movement can be equal to, greater than, or less than surface movement, independent of TBM performance.

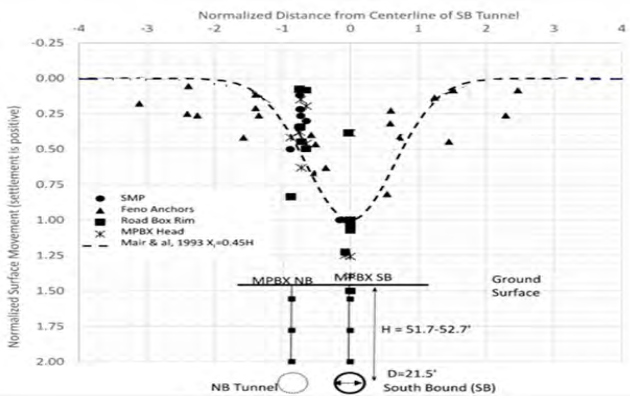

Figure 4. Normalized transverse settlement at MPBX 19 to 35 arrays

Evidence of ground movement changes observed at the MPBX bottom anchors was supported by transverse surface settlement troughs. Figure 4 shows normalized movements from reference survey points relative to the maximum movement, Smax, at the SMP nearest to the southern set MPBX. The southern set's normalized trough fits a curve with an inflection point at X=0.6 (H=51.7 - 52.7 ft for southern set), indicating a wider settlement trough. The northern set fits a Gaussian curve (Peck, 1969) with an inflection point at X=0.45H (H=52.7- 54.7 ft for northern set) and shows heave away from the centerline.

Interpretations of Deformations at the MLK Station: The heaving observed, instead of the expected settlement, is unusual for excavations. Settlement typically occurs due to: 1) inward movement of the ESS, 2) dewatering-induced consolidation, 3) internal heave causing exterior settlement, or 4) ground loss during ESS placement.

At MLK Station, the ESS is extremely stiff, limiting inward movement to ¼–½ inch, as shown by inclinometers—small compared to similar excavations. Minimal dewatering occurred due to deep original groundwater levels, and the high factor of safety in medium to stiff soils kept internal heave minimal. Additionally, ESS construction caused little to no ground loss.

With 65–68 ft of soil and water removed, significant unloading caused heave. Normally, this would be masked by larger settlements from typical mechanisms, which are insignificant here. The heave is expected to stop shortly after excavation completion.

CONCLUSIONS

Based on the observed tunnel induced ground movement pattern, it was necessary, for interpretation purpose, to aggregate these 18 MPBXs into two spatially distinct sets: a northern and a southern set.

Monitoring data indicated that following the bentonite injection and control system, the relative movement of the bottom anchor of the southern set was measured to be significantly less than before, even smaller than the surface movement near the MPBX location. This behavior was in contrast to the observed behavior of the northern set, where the relative movement of the bottom anchor was about equal or more than the surface movement.

The mechanisms that typically cause ground settlement around a deep excavation are not significant for the MLK Station. Since 65-68 ft of soil and water have been removed from the excavation large unloading took place contributing to heave. Normally such heave would be masked by the larger settlement from the mechanisms described above but that is not the case here. Such heave would be expected to stop soon after completion of excavation.

WHAT CAN DFI DO FOR YOU?

Overview

DFI is an international association of contractors, engineers, suppliers, academics and owners in the deep foundations industry. For more than 40 years, we have brought together professionals for networking, education, communication and collaboration. As a member, you help create a consensus voice and a common vision for continual advancement in the planning, design and construction of deep foundations and excavations.

Find Common Ground. Become a Member of DFI

- Network with thousands of members and industry professionals worldwide
- Get involved locally through DFI's active presence in Europe, India and the Middle East
- Strengthen your knowledge base and obtain practical information at seminars, short courses, workshops and conferences
- Collaborate with colleagues by joining one of 25 plus active Technical Committees, Regional Chapters or a DFI group
- Gain visibility with a corporate member listing on the DFI website, which has 20,000 views each month
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50th Annual Conference on Deep Foundations

Oct 20th - Oct 23rd, 2025

Abstracts are being accepted for original technical papers and panel sessions for DFI's 50th Annual Conference on Deep Foundations (#DFI50) to be held October 20-23, 2025, in Nashville, Tennessee. The theme of this international conference is "Celebrating 50 Years," focusing on the evolution of the industry. We will explore advancements in industry practices, techniques and project delivery through perspectives, case histories and research-based papers and presentations.

Abstract Submission Deadline: Monday, January 13, 2025

Submit here: *https://dfi-events.org/dfi50/cfa.html*

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