GUIDELINES

DESIGN AND CONSTRUCTION OF CONTINUOUS FLIGHT AUGERED CONCRETE PILE

Document No.: DFII/CFA/G/4/R0
APRIL 2020

PREPARED BY

CFA PILE TECHNOLOGY IMPLEMENTATION COMMITTEE
DEEP FOUNDATIONS INSTITUTE OF INDIA

BLANK PAGE

GUIDELINES

DESIGN AND CONSTRUCTION OF CONTINUOUS FLIGHT AUGERED CONCRETE PILE

Document No.: DFII/CFA/G/4/R0
APRIL 2020

PREPARED BY

CFA PILE TECHNOLOGY IMPLEMENTATION COMMITTEE
DEEP FOUNDATIONS INSTITUTE OF INDIA

GUIDELINES

Design and Construction of Continuous Flight Augered Concrete Pile

Document No.: DFII/CFA/G/4/R0, April 2020

Prepared by

CFA Pile Technology Implementation Committee
Deep Foundations Institute of India

Published by
Deep Foundations Institute of India
Non-profit company registered under Ministry of Company Affairs,
Government of India (Regn. No: U91900TN2013NPL091176)
44/17 'BHASKARA', 19 Usha Street, Dr. Seethapathy Nagar
Velachery, Chennai, TN, India

For copies (digital) and for more details contact
Deep Foundations Institute of India
Non-profit company registered under Ministry of Company Affairs,
Government of India (Regn. No: U91900TN2013NPL091176)
44/17 'BHASKARA', 19 Usha Street, Dr. Seethapathy Nagar
Velachery, Chennai, TN, India
Email: dfiindiaoffice@gmail.com, www.dfi-india.org

DFII CFA Pile Technology Implementation Committee

DFI of India (DFII) formed a committee, namely 'DFII CFA Pile Technology Implementation Committee' in 2018 to execute a CFA technology test pile project. DFI Committee Project Fund extended support to DFI India for this venture, which also received significant in-kind support and funding from Indian companies. The goal of the committee is to introduce and popularize the use of CFA piles to address the growing fast track piling needs in India.

DFII is very thankful to all committee members for volunteering their professional time and dedicated efforts in implementing this project successfully.

Members

1. Dr Sunil S. Basarkar, Geotechnical Head, Afcons Infrastructure Ltd, Mumbai (Committee Chair)
2. Dr K. S. Rama Krishna, Chair, DFII
3. Mr I. V. Anirudhan, Vice-Chair, DFII, Geotechnical Solutions, Chennai
4. Mr G. Venkata Prasad, Director of Operations, DFII
5. Mr Arvind Shrivastava, Outstanding Scientist and Associate Director (Civil), NPCIL, Mumbai
6. Prof. S. R. Gandhi, Director, SVNIT Surat
7. Mr Manish Kumar, Joint Executive Vice President, ITD Cementation India, Mumbai
8. Dr B. S. Sarma, Retd. Head, R&D, L&T Construction Division, Chennai
9. Mr Y. Hari Krishna, MD, Keller Ground Engineering India Pvt. Ltd., Chennai
10. Dr K. Pitchumani, Regional Director, AECOM, Chennai
11. Mr Ravikiran Vaidya, Principal, Geodynamics, Vadodara
12. Mr Sanjoy Chakraborty, MD, Soilmec India, Mumbai
13. Mr Jagpal Singh Lotay, MD, BAUER Equipment India Private Limited, Gurgaon
14. Dr Jaykumar Shukla, Principal Engineer, Geodynamics, Vadodara
15. Dr Vidyaranya Bandi, Geotechnical Consultant, Mumbai

DFI US Team

DFII team is grateful to the following team for providing guidance, support, handholding at every stage of the project and for the success of the project.

1. Mr Gianfranco Di Cicco, DFI Trustee, President & CEO, Bauer Foundation Corp, USA
2. Mr Morgan NeSmith, DFI ACP Committee Chair, US
3. Mr Stefano Cordella, Sales Director, Soilmec, Italy
4. Mr Franz-Werner Gerressen, Director, Method Development, Bauer, Germany
5. Ms Theresa Engler, Executive Director, DFI, US
6. Ms Mary Ellen Large, Technical Director, DFI, US
7. Mr Satyajit Vaidya, Vice President, Langan, US

DFI India Office Team

1. Mr Mohamed Athif, Manager – Operations, DFII
2. Mr J. Chandrasekhar (Ex DFII)
3. Mr Pranav Jha, Assistant Manager – Operations, DFII
4. Mr T. S. Mahendran, Manager – Admin & Accounts, DFII

Accomplishments

1. The demonstration project, involving design, installation and testing of CFA piles, was successfully conducted between November 2017 and November 2019 through joint efforts of DFII team and the industry.
2. Testing of these CFA trial piles was conducted during Nov'2019. Two piles each were tested for Vertical Compression, Pull-out and Lateral load-carrying capacities. All tests revealed that ultimate capacities are 15 to 20% higher than the estimated capacities. While this is a very positive outcome of our trials, an upward revision of design input parameters can be recommended after more pile load tests in the future.
3. The committee developed the following documents to aid the Indian Construction Industry in implementation of this technology in all major infrastructure projects wherever the sub-soil conditions suit.
    a. CFA Trial Pile Design and Construction Document (Covers geotechnical characterisation, geotechnical design of CFA piles, concrete mix design procedure and construction and testing programme)
    b. CFA Trial Pile Installation Report (Covers the important technical, planning, logistics, equipment details for construction two probe piles and six test piles)
    c. CFA Trial Pile Test Report (Covers data and interpretation of all load test results)
4. Guidelines for Design and Construction of Continuous Flight Augered Concrete Pile (the present document) is available to all major stakeholders for facilitating the adoption of this technology in India.

This committee shall continue to put further efforts in facilitating implementing CFA pile technology in many future projects in India.

DFII CFA Test Pile Project - Industry Support

Acknowledgement

The success of DFII CFA Test Pile project is an outcome of the collective efforts of all stakeholders since 2017. DFII is ever grateful to many proactive organisations who came forward to offer an in-kind contribution and financial donations in the installation and testing of CFA trial piles.

Summary status of support received from different organizations is presented below.

CFA Test Pile Project - Support from the Industry

In-Kind Contribution	Details
Nuclear Power Corporation of India Limited (NPCIL), Mumbai	Providing land for the conduct of CFA trial piles in their greenfield project at Haryana and provided quality control services.
ITD Cementation India Ltd., Mumbai	Providing resources, supervision, site infrastructure for concrete, reinforcement fabrication, and pile testing work.
Soilmec India, Mumbai	Providing CFA kit, assembling CFA kit including operators form Italy and India and test pile installation
Ultratech Cement	Supply of cement
Tata Projects Limied, Mumbai	Supply of electrical cables, load-carrying vehicles
SCHWING Stetter (INDIA) Pvt. Ltd	Supply and operation of concrete pump
Smart Structure (Radise Group) US	Instrumentation and related analyses for two piles
PDI, US / Geo Dynamics, Vadodara	Thermal integrity profiling of two piles
BASF Chemicals, Mumbai	Supply of admixture
Asahi Ropes, Delhi	Supply of wire ropes
Balaji Enterprises, Chennai	Supply of cover blocks

Financial Donations	Amount (INR)
L&T Construction, Chennai	1,000,000
Tata Projects Limited, Mumbai and Saritha Infra & Geo-Structures	1,000,000
Keller Ground Engineering India Pvt. Ltd., Chennai	500,000

Financial Donations	Amount (INR)
IRB Infra, Mumbai	400,000
Afcons Infrastructure Ltd, Mumbai	250,000
Manjeera Constructions, Hyderabad	100,000
SKCL Developers, Chennai	100,000
Advance Construction Technologies, Chennai	100,000
Dr. K S Ramakrishna, DFI of India	100,000
Smart Structures (Radise Group), US	60,000
Mr. G Venkata Prasad, DFI of India	30,000
Financial Donation Total	**36,40,000**

DFI of India offers profound thanks to all these organizations and their leadership for this timely support for the CFA test pile project.

FOREWORD

In modern times, the pace and quantum of economic development of a country depend heavily on its temperament and ability to develop or to adopt technologies. A great example is that of India in the fields of Information Technologies, space, and nuclear technologies. India has now set its sight on becoming a 5 Trillion Dollar economy, and towards accomplishing this milestone, the government of India has announced plans to invest around Rs.100 Lakh Crores in infrastructure projects in the next five years. Most of the infrastructure development involves the creation of the physical infrastructure, which means the great scope for Civil Engineering and Construction in our country.

Foundations construction being the first physical and principal activity in a construction project site, the global experience suggests that projects that do not complete foundations in time end up in major cost escalations and time delays. It is important to recognise that key factors, viz., technologies, modern equipment and skilled workforce in foundations construction play a significant role in the faster completion of a project. Unfortunately, this is not the case in India now, as we are far behind in all these key areas. Recognising this situation Deep Foundations Institute of India (DFI of India) has embarked on major initiatives in the areas of technologies implementation and skill training. The strategy is to introduce appropriate and matured technologies through a technology demonstration field trial and based on the success prepare a guideline manual for design and construction. After gaining enough experience in a few years, this manual can form the basis for creating an Indian Code of practice. As a first case, DFI of India has identified Continuous Flight Augur (CFA) Pile Technology as one that has a great potential to improve the speed of installing pile foundations in India.

For historical reasons, Bored Cast-in-Situ Pile is the most common deep foundation type in India. As a result, most of the modern foundation equipment in India belong to this category. CFA piles can also be installed using the same modern bored piling equipment but with slight modifications/change of accessories. Use of CFA piles would result in a pile installation productivity jump of at least three times when compared to that of bored piles.

In December 2016, I had the opportunity to submit a project proposal to the Board of Deep Foundations Institute (DFI), USA (the parent body of DFI of India) for funding a technology demonstration project of installation and testing of CFA piles in India. The idea was to first demonstrate the technology by installing a few CFA piles in the presence of most of the stakeholders of the foundation industry in India, test them and then to prepare a manual for design and installation of CFA piles. The success of this would give the necessary confidence

to the industry to adopt this technology in several projects across India. Implementation of this CFA pile technology would benefit all stakeholders- the owners of projects (early project completion), the main contractors (early project completion) and the piling contractors (higher productivity and economy), and ultimately our country (faster infrastructure development). In April 2017, the DFI Board (USA) approved a project fund of US$30,000. We still needed to raise around US$40,000 in India through cash and in-kind donations.

Encouraged by the grant, a CFA Pile Technology Implementation Committee was formed with Mr Jeyson J. Samuel, a promising foundation engineer from L&T GeoStructure and my former colleague, as the coordinator. He immediately took up this with Mr Arvind Shrivastava, Chief Engineer (Civil) and Head of Civil Engineering Group in Nuclear Power Corporation of India Limited (NPCIL), who readily agreed to allow the field trial at one of his greenfield project sites. Subsequently, I had requested Dr Sunil S. Basarkar, General Manager (Geotechnical) AFCONS Infrastructure Ltd and Member of DFI of India Executive Committee (formerly, General Manager (Design) in ITD Cementation), to take the mantle of coordinating this important initiative. Despite pressing demand from his professional occupation, Dr.Basarkar not only agreed to my request but also admirably steered the project to its complete success.

The field soil investigation was carried out, and the data was used by the technical committee to carry out the CFA Pile design. The design, installation and testing document was prepared under the able guidance and active involvement of Mr I.V.Anirudhan, Managing Director of Geotechnical Solutions and Vice-Chairman of DFI of India and was reviewed by the experts in DFI USA, Soilmec Italy and Bauer Germany.

I would like to briefly mention the journey of the technology demonstration of the CFA pile in India. DFI of India could not avail the project fund granted by DFI, USA as our application to the Government of India for Foreign Currency Regulation Act (FCRA) approval was turned down. As a result, the onus of raising the entire fund fell back on DFI of India. Thanks to the great efforts of Mr G.V. Prasad, Director (Operations) of DFI of India and his office team, we managed to not only raise most of the fund required but completed the field trial of installation and testing of six(6) CFA piles with great success. The field trial was witnessed by several stakeholders. It is noteworthy to state here with gratitude the encouragement, cash and in-kind support received from more than twenty (20) national and international organisations and individuals. The success of the field trial has given the necessary impetus to the technical committee led by Dr Sunil S. Basarkar and Mr I.V. Anirudhan to prepare this manual.

The manual is aimed at preparing necessary guidelines for the design and installation of CFA piles in India. It gives in detail, the design process involved for both cohesive and cohesionless soils. As an added benefit to the user, a step-by-step design example is also provided in one of the Annexures. Specifications for materials of construction, viz., concrete,

grout, reinforcement are given in good detail. The equipment and accessories required, and the procedure of pile installation are provided with necessary detail. Topics such as load testing, integrity testing and pile instrumentation are also covered. It is to be noted that CFA piling is only one of a few methods of forming a cast-in-situ concrete pile and that all other aspects, viz., integrity and load testing are very similar to that of bored cast-in-situ piles. The manual provides references to the various codes and other standard publications for load and integrity testing, materials, etc.

It is natural for the owners, consultants and contractors alike to hesitate to try new technology in their projects for the first time, however well established and widely practised the technique is in other countries. Fear of failure and the consequent damages to the project are probably the main reasons for such hesitation. DFI of India, therefore, decided to demonstrate the technology including load and integrity testing at a neutral site in India in the presence of all stakeholders and it is gratifying to mention here that the attempt was a grand success. This design and installation manual is based on the first-hand experience gained by the DFI of India technical committee of all the steps involved, i.e., soil investigation, pile design, equipment assembling and transportation to site, material selection, mix design, fabrication, instrumentation, load and integrity testing, etc. It is hoped that users of this manual would bank on this experience and implement CFA pile technology in their projects where the conditions are favourable and reap the rewards from this faster and economical piling alternative.

The phenomenal support provided by Theresa, Executive Director, DFI, Mary Ellen, Technical Director, DFI and other DFI leadership at every stage of the project including a) providing us with all relevant CFA pile technical documents and expertise and b) in garnering international support for the smooth execution of the project.

Vijayawada
April 28, 2020

Dr K.S. Rama Krishna
Chairman DFI of India
Member Board of Trustees DFI, USA

BLANK PAGE

GUIDELINES FOR
DESIGN AND CONSTRUCTION OF
CONTINUOUS FLIGHT AUGERED CONCRETE PILE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUPPORTING DOCUMENTS

Document No.: DFII/CFA/D&C/1/R3 – 15 JANUARY 2019

DOCUMENT FOR PILE DESIGN & CONSTRUCTION BY CONTINUOUS FLIGHT AUGER (CFA) – A TECHNOLOGY INITIATIVE BY DFI OF INDIA

Document No.: DFII/CFA/PIR/2/R0

CONTINUOUS FLIGHT AUGER (CFA) TRIAL PILE INSTALLATION REPORT AT NPCIL SITE, GORAKHPUR, HARYANA, DATE OF TRIALS: 27 – 30 MAY 2019

Document No.: DFII/CFA/LTR/3/R0 -NOVEMBER 2019

COMPENDIUM OF LOAD TEST REPORTS ON CONTINUOUS FLIGHT AUGER (CFA) TRIAL PILES - LOCATION: GORAKHPUR, HARYANA