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 ijirset@gmail.com

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Case study on Construction of Monopile & Quality Parameter

Er. Vivek Kale¹, Prof. Tushar Bhamare²

P.G. Student, MITCOM, MIT ADT University, Pune, Maharashtra, India¹

Assistant Professor, MITCOM, MIT ADT University, Pune, Maharashtra, India²

ABSTRACT: This case study presents for Monopile pile construction in marines and land, and its Quality control parameter.

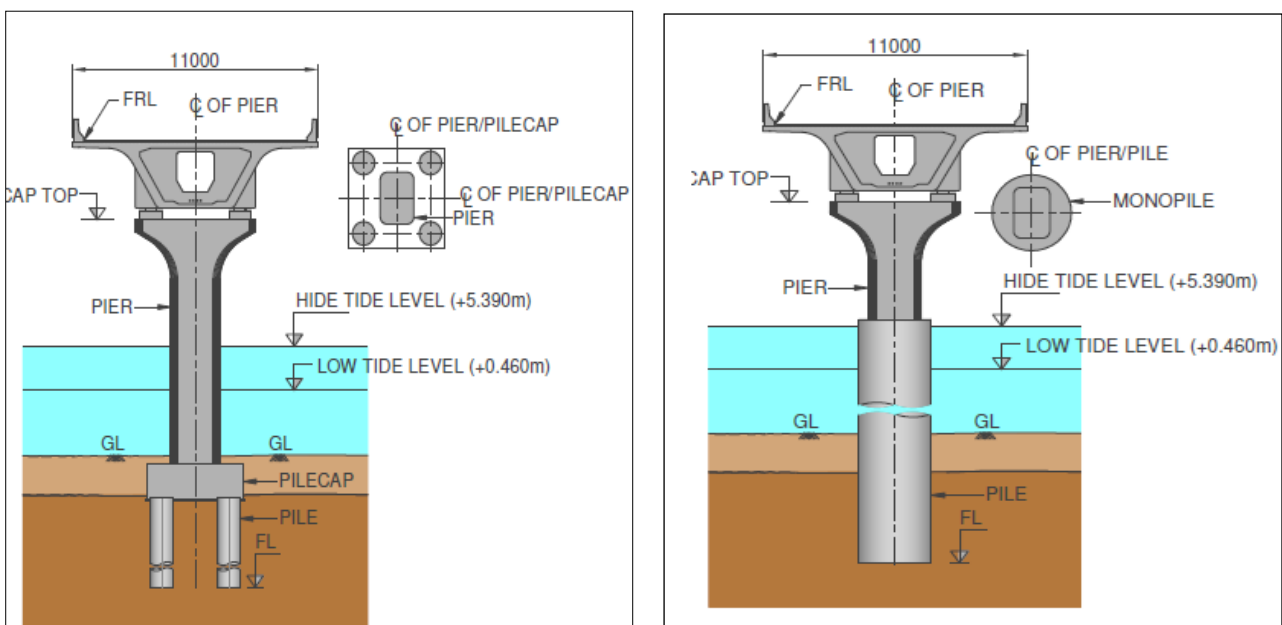
- a) The design of Monopile foundation shall comply with relevant provisions of latest AASHTO LRFD specifications for non-redundant foundation systems.
- b) The design shall comply with operational classification corresponding to critical Bridges (open to emergency vehicles after 2500-year seismic event).
- c) The Monopile foundation design shall be primarily & mainly as per provisions of latest AASHTO LRFD specifications and then hierarchy of other relevant codes as specified in the contract shall be followed.

KEYWORDS: AASTHO LRFD - Bridge Construction Specification, Monopile foundation, PBA- Pile Boring Assembly, BHA – Bore Hole Assembly, RCD - Reverse Circulating Drilling.

I. INTRODUCTION

This case study of Monopile construction technique adopted against the method of traditional pile work in bridge construction work, crossing seashore area, due to the following reason technique was adopted for the bridge work, which has been widely used in the offshore wind turbine construction.

In view of aesthetic projection designer provided pile cap, below tide water level and 500mm below seabed level which is difficult and time taking, bunch of construction sequential activities as, Sheet piling / Cofferdam, Excavation, Shuttering/ Anchoring, Dewatering, Piling, Pile cap, Pier, and then again removal of sheet pile coffer dam.



Typical cross Section of Group piles and Monopile Foundation System



II. METHODOLOGY

Sequence of activities shall be as follows.

- 1) Survey and positioning of Jack up platform,
- 2) Setting out pile point,
- 3) Precast collar installation at pile location,
- 4) Lowering of the liner,
- 5) Sealing / Plug concrete,
- 6) Placing of guiding frame & working platform,
- 7) Installation of BHA & PBA unit,
- 8) Drilling of pile,
- 9) Removing BHA & PBA,
- 10) Prefabrication of reinforcement cage,
- 11) Lowering of prefabricated reinforcement cage,
- 12) Concerting of pile,
- 13) Removal of precast collar

A) Details of Major equipment's

1) Drilling Equipment

PBA Assembly

PBA 936

A reversed circulation (air lift) Pile Top Drill rig make "WIRT" Type PBA 936 - for drilling 3 Meter -3.5 Meter Monopile Drilling.

Total weight – 31 Ton

Technical Specifications of PBA936		
Drill mast operation load	Max. Thrust Force	1000KN
	Max. Pull Back	1700KN
Stroke	3.5m	
Retaining Doors	For Drill Pipe	NW 300
	Free Passage	3030mm
Hydraulic Power Swivel	Torque	360 KNm
	Rotation	9.4-22.4 rpm
Total Weight	31 Ton	

2) BHA Assembly

Bore Hole Assembly for Drill Bit 3.5 Meter.

Total Length (Approx) – 12.2 Meter

Total Weight – 88.8 MT

Drilling Process

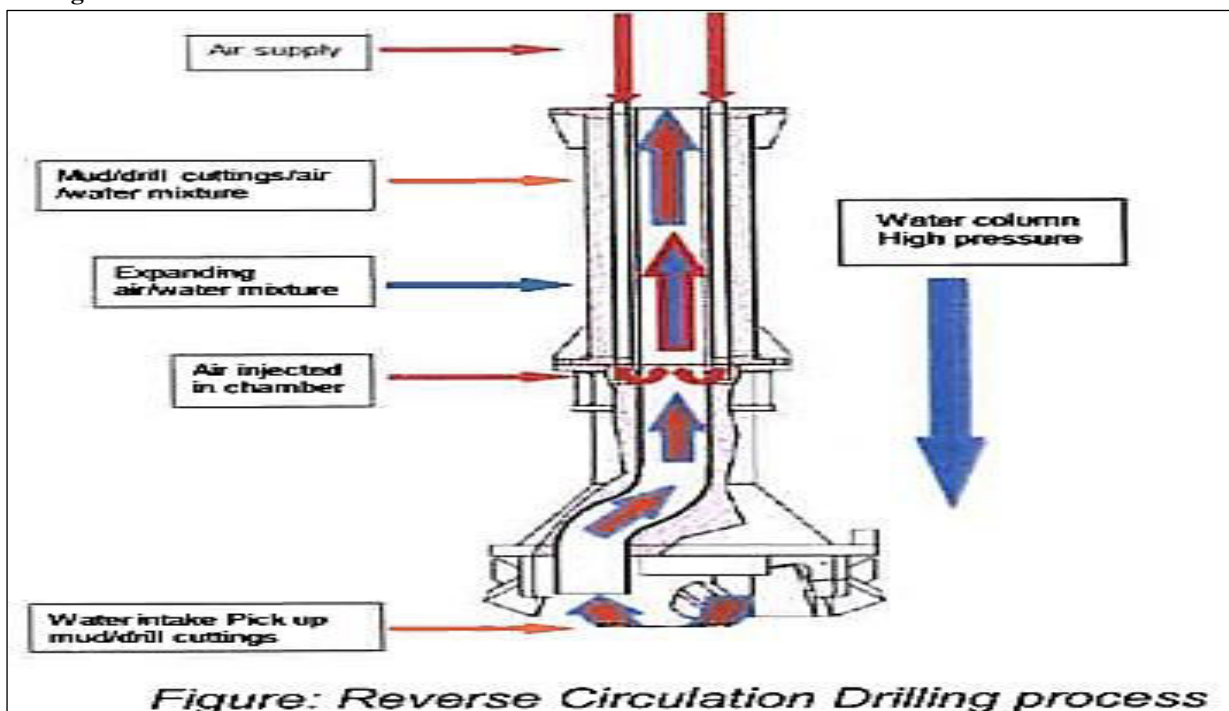


Figure: Reverse Circulation Drilling process



B) Mix design, Workability Durability Tests requirements.

Mix Design - M60

Grade of concrete	M60
OPC cement (kg)	360
Fly ash (kg)	205
Micro silica (kg)	35
Aggregate 10mm (kg)	503
Aggregate 20mm (kg)	411
Crushed sand (kg)	640
Wash Sand (kg)	160
Admixture Super plasticizer (kg)	8.70
Admixture corrosion Inhibitor (kg)	3.0
Water (kg)	142
Water cement ratio	0.236

Workability

Flow required - 650+/-50mm @ batching plant and at site 600+/-50mm for 06 hrs. retention.

Durability requirements

- Rapid chloride penetration test (RCPT) by BS EN12390-8:2000 <1000 coulombs
- Water permeability test by DIN 1048 method <10mm
- Initial surface water absorption test (ISAT) by BS 1881 which is not more than 0.25 ml/m²/s
- Chloride migration coefficient test (CMT) by Nord test method NT Build 492 which is < 2 x 10⁻¹² m²/s

C) Tests carried out,

Initial pile load test.

Initial Pile load test carried on site as location has been decided after examining all the borehole investigations which carried out.

Vertical pile load test conducted by “O” (Osterberg) cell load test method by bidirectional static load test (BDSL)

The test procedure shall be in accordance with ASTM D8169M standard [5].

For lateral capacity, conventional load testing shall be carried using steel jack in between two reaction piles, in accordance with ASTM D 3966-07 [6]. The reaction pile to be used for lateral load test could be the 3.5m diameter pile already tested for vertical capacity. As per Monopile committee recommendation’s, lateral load capacity obtained from the test pile shall be used for Monopile.

• **Instrument for Lateral Pile load Test**

Instruments shall be used for lateral pile load test are as follows:

- Down hole inclinometers at key loading stages to measure pile deformation,
- Dial gauges or similar at the head of the pile, and Load cells to be used at the head of both the lateral test pile (2.5m dia.) and reaction pile (3.5m dia.) to confirm the load distribution from the jack onto both piles.
- Strain gauges attached to the pile reinforcement to monitor the deflection.

Imp. Note

As per clause A10.2 of AASHTO (LRFD Bridge Design Specifications 8th Ed 2017), the ultimate lateral resistance is the load where the pile head deflection has reached 3d/80 (where d is the diameter of the pile). In this case, the limiting deflection of pile head at + 8.3m MSL during the lateral load test shall be 131.5 mm for 3.5 m dia pile.

As per IRC 78 (2014), Lateral deflection at scour level shall be restricted to 1% of the pile diameter.

Instrument for Vertical Pile load Test

Instruments shall be used for Vertical pile load test are as follows:

1. Down pile extensometers to monitor deformation of the pile above and below the O Cell,
2. Extensometers at other key levels down the pile, Hydraulic jack 4Nosx900M,
3. Pile head settlement monitoring, and
4. Strain gauges attached to the pile reinforcement to monitor the shedding of shear



Typical details of O cell arrangement



Installation process of O-Cell in cage

D) Stress & strain instrumentation

Cross Sonic Logging test

The cross-hole sonic logging test on bored pile installed at the site. The aim of testing was to assess and check the pile integrity for potential problems like cross-sectional changes, honeycombing, concrete quality, continuity, etc.

Cross-Hole Sonic Logging generally applies to drilled shafts and requires that at least three tubes be installed in a drilled shaft prior to pouring the concrete, in 3.5mtr dia installed 10Nos tubes and that stress pulses are sent from one tube to the other at 50mm vertical intervals. The arrival time of the pulse at the receiver tube indicates the quality and integrity of the concrete between the tubes.

For conducting the sonic logging test mild steel tubes as described earlier were installed throughout the length of the shaft by tying them to the reinforcement cage. They were filled with water and the top and bottom of the tubes was sealed before concreting. This was to take into account the differential temperature during concreting and curing.

The test can be conducted after minimum 3 to 7 days of concreting. For this a transmitter is lowered in one of those tubes and a receiver - in another. Both transmitter and receiver are connected by cables to the Cross Hole Analyzer (CHA), which records the arrival time and the energy attenuation as the probes are simultaneously raised to the top. As long as the arrival time and the energy attenuation are roughly constant, one may deduce that the concrete quality is also uniform, and the pile is therefore acceptable.

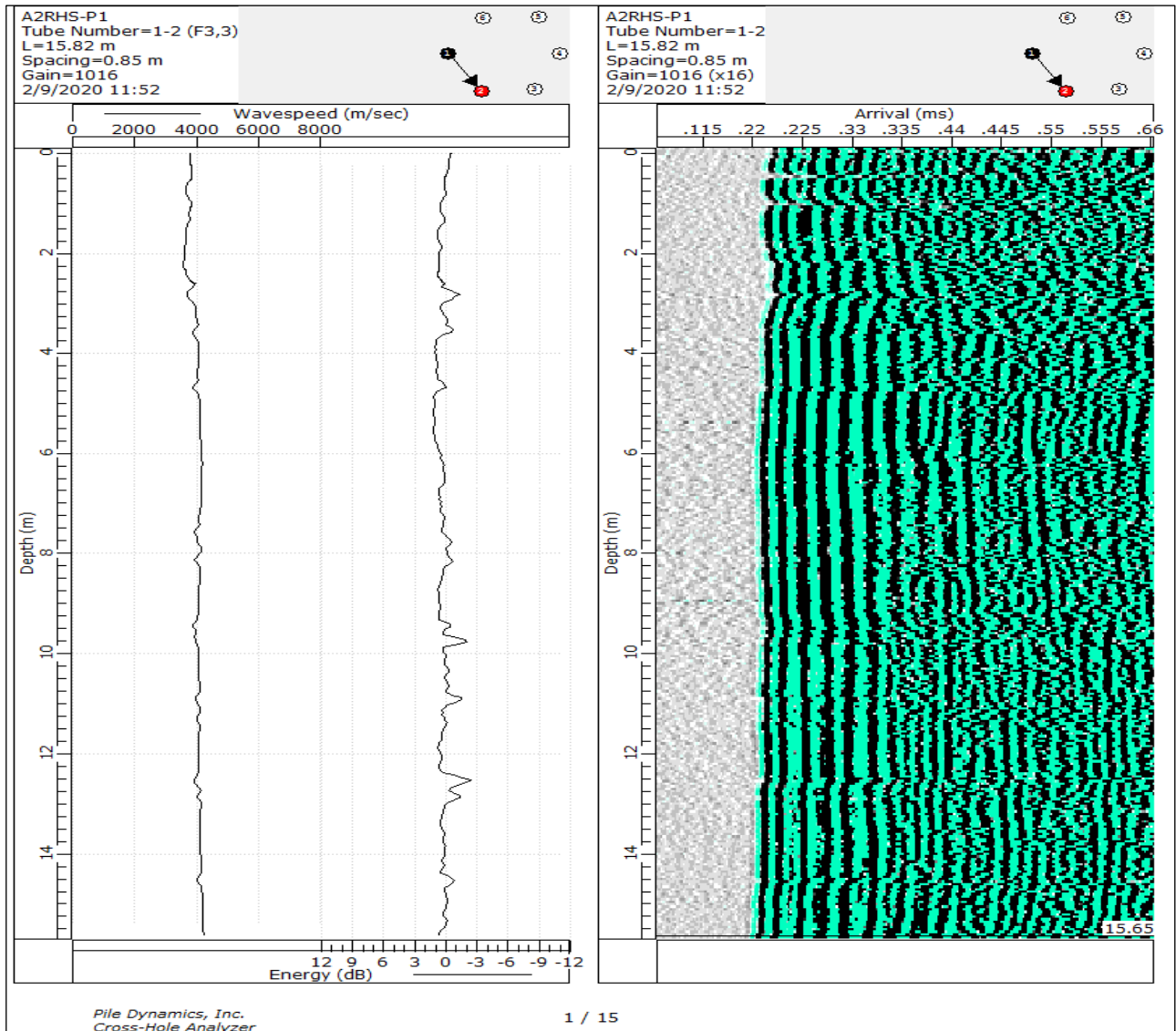


Pile Classification	Pile Acceptance Criterion	Comment for Defect	FAT Increase relative to good concrete	Energy reduction relative to good concrete
Class A	Acceptable CSL Test Results	Minor	0-0-15%	< 9db
Class B	Conditionally Acceptable CSL test Results	Poor/Flaw	15-30%	9 to 12db
Class C	Highly Abnormal CSL test results	Poor/Defect	>30%	>12db

- 1) If more than 50% of the scans which includes at least one cross-scan are in category B at the end of the test, then the shaft is treated as in Category C and further investigation may be conducted.
- 2) Similarly, if at least 2 scans which includes one diagonal or cross scan are in Category C at the end of the test, then the pile shall be considered to be in Category C and further Investigation may be conducted.

III. RESULTS OF CROSS HOLE SONIC LOGGING TEST

Sr. No.	Pile No. & Pile Depth	Tube Corridor	Tube Spacing (m)	Average Wave Speed (m/sec)	FAT Increase relative	Energy Reduction	Location of FAT & Energy Reduction	Comments	Pile Integrity
1	XYZ (15.65m)	1-2	0.85	4095	0-15%	<9db	0m-16.77m	Uniform pile shaft. A	A
2		2-3	0.76	3995	0-15%	<9db	0m-16.77m	Uniform pile shaft. A	A
3		3-4	0.76	4152	0-15%	<9db	0m-16.77m	Uniform pile shaft. A	A
4		4-5	0.76	4068	0-15%	<9db	0m-16.77m	Uniform pile shaft. A	A



E) Dynamic load test.

The aim of testing is to evaluate pile static capacity and measure the settlement. Report presents the results of dynamic pile testing and analysis performed using the Pile Driving Analyzer (PDA) and Case Pile Wave Analysis Program (CAPWAP). The test is conducted in accordance with ASTM D4945.

Pile No.	Test Pile
Pile length below gages	17.6 m
Pile length below grade	17.3 m
Liner length from COL	10 m
Concrete Grade	M60
Pile Diameter	3500mm
Hammer Weight	12 T
Weight 12 T	1.25 m
Drop Height	



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Working Load	6529.0
Test Load	16322.5
Maximum Compressive stress allowable	0.85fck =51.0 N/mm ²

III. CONCLUSION

- 1) In Durability test chloride migration coefficient achievement less than 2×10^{-12} m²/s. After taken number of trials final conclusion we achieved CMT less than 2×10^{-12} m²/s at 56 days of age of concrete.
- 2) Initially at the time of charging upto one meter built up 10cum concrete Qty required. So, arrange Hopper and crane bucket to fulfil the charging requirements i.e., 7cum hopper and 04 cum of 02 Nos crane bucket that means total 15cum concrete at a time of changing in one go.
- 3) Pile boring is huge challenging for 3.5mtr dia. which is done by RCD (Reverse circulation Drilling) Method

Cost implication

The original scheme of Bridge was planned with group pile foundation for substructure of the Main line and Interchange bridges. Considering geological strata at the site and to mitigate challenges posed to work with conventional cofferdam arrangement for group pile and pile cap execution works especially in the intertidal zone, a value engineering proposal to consider large diameter piles to Monopiles as an alternative to group pile scheme. Cost of Group is Rs129 crore, and that of Monopile cost is 122.2crore, saving of Rs 6.8crore with 03-month times saving.

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