Case Study on Sustainable Deep Pile Foundation-Bored Cast In Situ Piles on Rupsha Bridge at Bangladesh through Base Grout Technology

[1]Amal Bhattacharya, [2]Ravi R Rasimoni.
[1]Sr.Deputy General Manager & Project Manager, [2]Sr. Design engineer
[1]Khulna Mongla Bridge Project, Khulna- Bangladesh,
[1]amalbh@lntecc.com, [2]RRKL@lntecc.com

Abstract: **The Government of Bangladesh has embarked upon the construction of a Broad Gauge (BG) rail link from the city of Khulna to Mongla Port. It is basically the extension of the existing rail line serving Khulna, to the Mongla Port. Establishment of the Khulna-Mongla railway would directly connect the Mongla port with the rest of the country; as a result, commodities would be easier to transfer to different parts of the country including the capital from the port.**
The main objective of the work is to construct Railway Rupsha Bridge over the river Rupsha for Construction of Khulna-Mongla Port rail line to provide connectivity to Mongla Port with the existing railway network of Bangladesh Railway which will eventually lead to regional & sub-regional connectivity.The source of public funds is Indian Dollar Credit Line (loc) and Government of the People's Republic of Bangladesh (GOB). The Government of India is providing Line of Credit of USD 1 billion (since reduced to USD 800 million) through Exim Bank of India to Government of Bangladesh. One of the components under this fund is development of rail link between Khulna and Mongla Port.

I. PROJECT IMPLEMENTATION:

The civil works under contract Package WD2 comprises of Construction of Railway Bridge over the river Rupsha and implementation of EMP. The executing agency, LARSEN & TOUBRO Infrastructure of India, has been awarded the civil contract for BDT 1076.5 crore with project duration of 42 months.

II. PROJECT SCOPE:

The Railway Bridge overRupsha river consists 69* 32.45 + 7*102.4+67*32.45 = 5.13 Km. The superstructure for approach is composite and for main bridge (7* 102.45 m) is open Web steel girder.Originallythe approach bridge foundation was designed with 6 Nos 1500 mm Dia. and 40 m length of bored cast in situ pile .Viaduct (136 pier foundation @ 32 m c/c) : 1500 mm Dia. Bored cast in situ pile of 45 to 60 m length(pile design vertical capacity 575 to 460 ton)

1. Main bridge (8 foundation) : 2500 mm Dia. bored cat in situ pile of 69 to 72 m length (pile design capacity is 1000ton)
2. Pier and pier cap (up to 18m height)
3. Superstructure : E 250 grade (BO)
4. Viaduct : Box girder (90 ton per each span) and concrete deck
5. Main bridge : steel through Girder : 107 m span (750 ton per span)
6. Grade of Concrete: M40 approx. & concrete quantity:1.8 lacks cum.
7. Grade of Reinforcement steel: (Fe 500): & Reinforcement quantity: 23000 ton
8. Grade of Structural steel: E 250 grade (BO) & Steel Quantity: 18000 ton

Geo Technical investigation: The geo technical investigations were carried out for 65-70 m depth at pier location to ascertain the actual soil strata. Abstract Long profile of sub surface soil strata showing different soil layers and the SPT N value is provided in below table. The SPT N values is upper zone (0 to 10 m depth) are generally less than 10 and at higher depth beyond 35 m below are more than 20 and varies up to 50. The soil layers generally silty sand /silty clay and Ø ranges 25to 32.

III. GTI INFORMATION & SOIL PROFILE:

Table 1: GTI information

BH No.	Layer	Soil description	Depth		Υ_{Sat} (kN/m^3)	Υ_{Sub} (kN/m^3)	Avg field N value	Soil parameters	
			From (m)	**To (m)**				**C (Kn/m^2)**	**Ø (deg)**
P66	1	Silty sand	0	14	17	7	3	0	0
	2	Silty sand	14	18	17	7	15	0	26.2
	3	Silty sand	18	24	18	8	30	0	26.7
	4	Sand	24	33	18	8	22	0	26.7
	5	Sand	33	36	18	8	36	0	26.7
	6	Silty clay	36	42	18.6	8.6	12	61.7	0
	7	Sandy silt	42	50	19	9	42	0	32.5
	8	Silty sand	50	60	19	9	35	0	24.6

SOIL PROFILE

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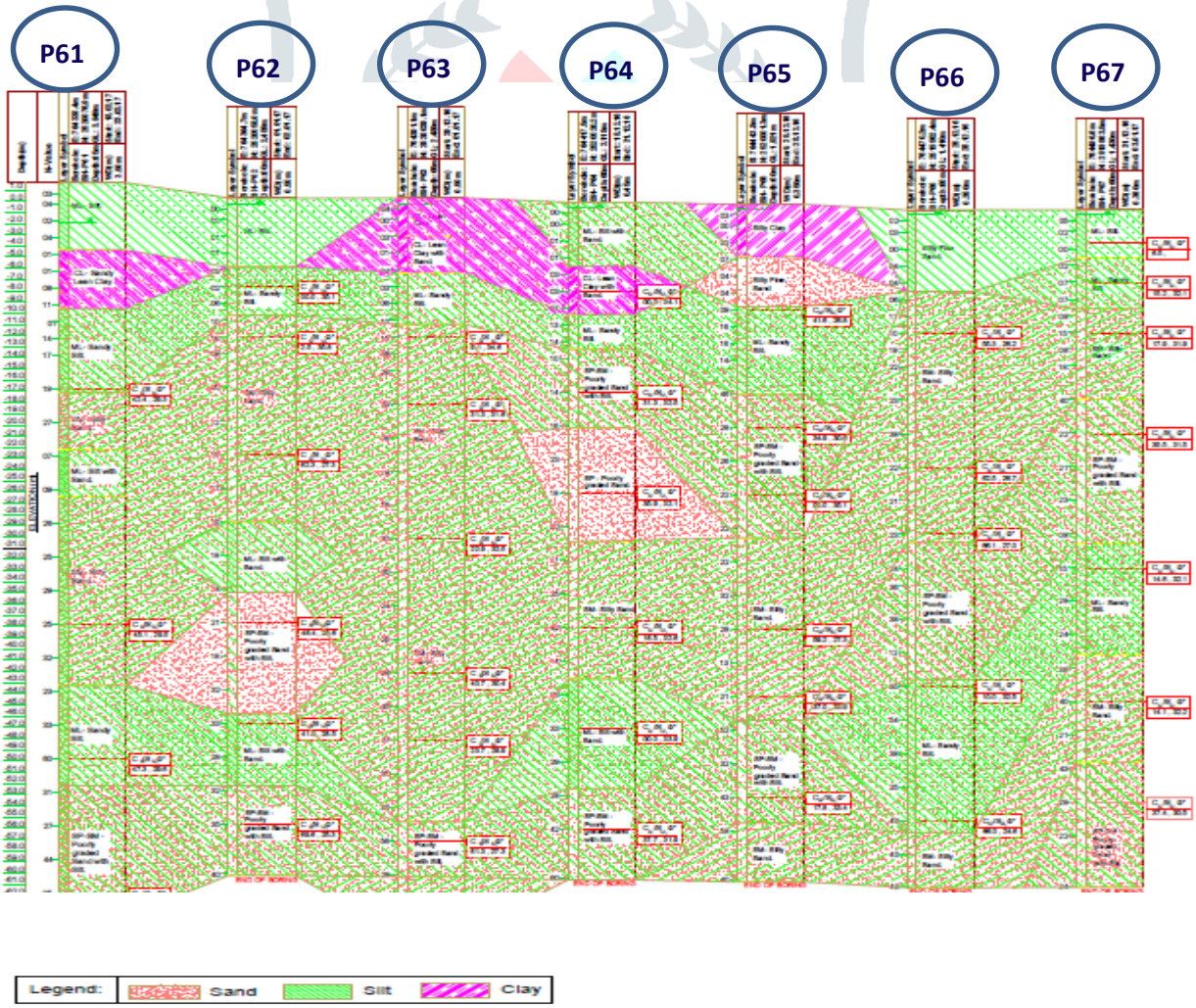

Figure1: soil profile

Table -2: Vertical Load test chart (TP-1, TP-2, TP-3 & TP-4)

S. No	Test Pile Details	Vertical Test Pile -1 (TP-1)	Vertical Test Pile -2 (TP-2)	Vertical Test Pile -3 (TP-3) with base grout	Vertical Test Pile -4 (TP-4) with base grout
1	Pile Diameter	1.5 m	1.5 m	1.5 m	1.5 m
2	Length of plie	40.0 m	52.0 m	45.0 m	52.0 m
3	Design Vertical load	570 MT	440 MT	570 MT	570 MT
4	Vertical target test load	1450 MT	1140 MT	1450 MT	1450 MT

IV. Lateral Load test chart (TP-2, TP-3 & TP-4)

Table -3: lateral load test chart

S. No	Test Pile Details	Lateral Test Pile (TP-2)	Lateral Test Pile (TP-3) with base grout	Lateral Test Pile (TP-4) with base grout
1	Design Lateral load	5 MT	6.8 MT	6.8 MT
2	Lateral target test load	12.5 MT	37.0 MT	20.4 MT

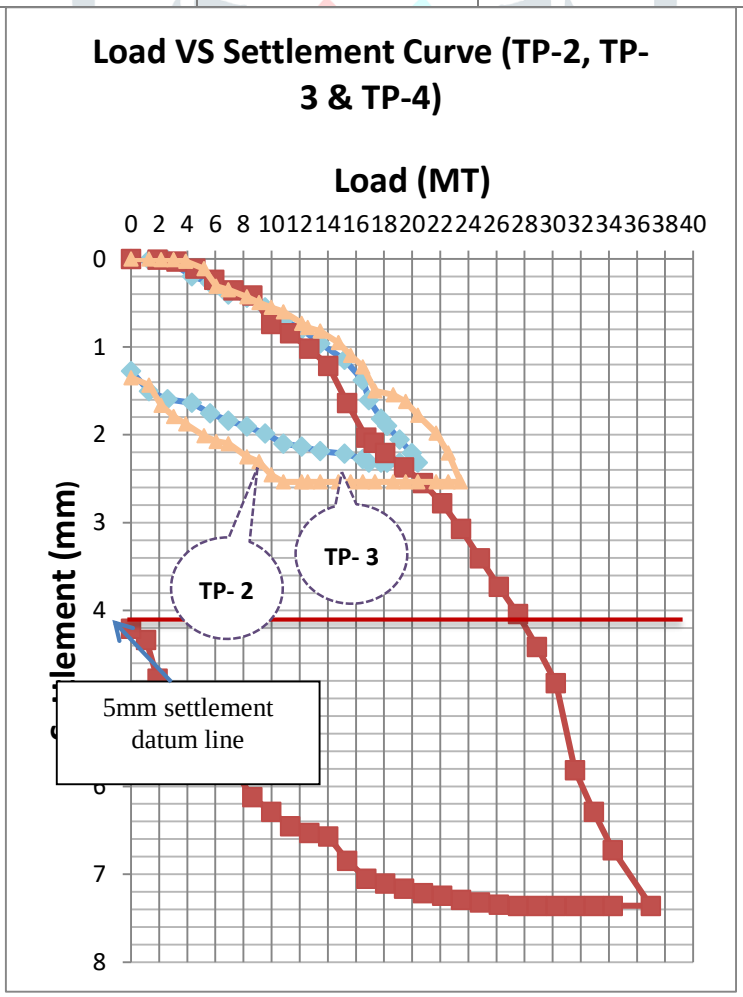

Figure 2- Load Vs Settlement curves

V. BASE GROUTING:

Purpose of Base grouting:

1. Base Grout piles are mainly used for structures which require piles of relatively high service loads.
2. Base grouting for bore pile is the key procedure to and hence the pile bearing capacity by improving both skin friction of shaft and end bearing of pit.

Base grouting Methods:

1. Tube a manchette method
2. Flat jack method

Tube a manchette method is being followed in KMBP project.

Base grouting arrangement:

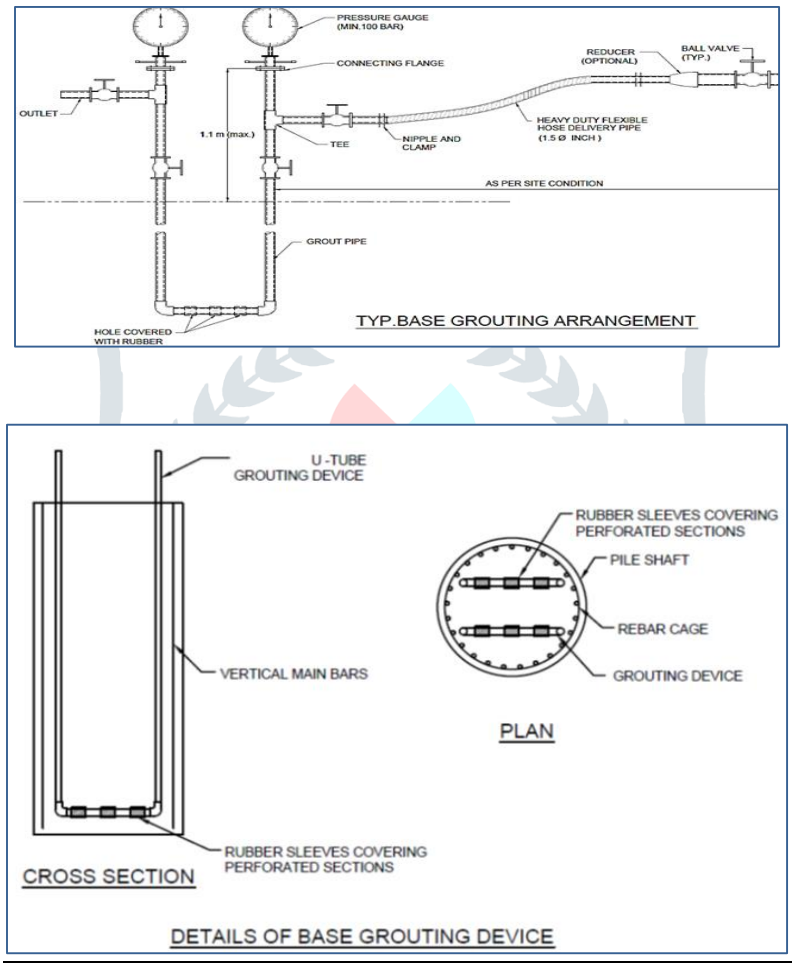

Figure 3- Base grouting KMBP site photos**:**

Figure 4: grouting

Tube a manchette method followed as per stage by stage grouting:

Stage 1 Grouting:

Sl. No	Items	Details	Remarks
1	Purpose	Filling and Sealing of surrounding soil at base of pile by permeation grouting at pile toe level, with some compaction grouting achieved depending on sustainable final pressure.	
2	Starting Time	When the pile concrete strength is at least 20 MPa. Temperature is less than 30 degree Celsius.	
3	Water Cracking Check	To be done separately for each circuit less than 12 hours	
4	Grout Mix (for 1000 L)	Cement - 1115.7 kg, water cement ratio – 0.5, Water - 557.7 kg, Admixture 1% of cement weight BASF-Master flow150 – 11.15 kg. Bentonite 3% of cement weight – 33.47 kg	
5	Total Grout Volume	Target 447L maximum in Stage-1. During injection to separate circuit maximum grout volume per circuit is 145L (i.e. maximum 290L for two circuits).	

6	Injection Rate	10 lit/minute for each separate circuit, then	
		5 lit/minute during Pressure Holding Time.	
7	Injection and Maintaining	3.0 MPa maximum, during injection of each circuit.	

Stage 2 Grouting:

Sl. No	Items	Details	Remarks
1	Purpose	Achievement of target soil bearing capacity at limited displacement of pile through "compaction grouting".	Target maintained pressure, minimum 3.0 MPa up to maximum 6.0 MPa.
2	Starting Time	Minimum 24 hours after completion of 1st Stage grouting or when the grout cube strength from 1st batch of Stage-1 grout achieves at least 20 MPa whichever is later.	Stage-1 grout test sample to be tested at suitable intervals to confirm when 20MPa is achieved.
3	Water Cracking	Same as stage-1	
4	Grout Mix (for 1000 L)	Cement - 1115.7 kg, water cement ratio – 0.5, Water - 557.7 kg, Admixture 1% of cement weight BASF-Master flow150 – 11.15 kg. Bentonite 3% of cement weight – 33.47 kg (same as in Stage-1)	
5A	Grout Net Volumes (Separate TAMs)	Maximum volume of grout in each circuit is 50L or maximum pressure ≥ 3.0 MPa achieved whichever is earlier.	Total volume in all two TAMs ≤100L
5B	Grout Net Volumes	Additional grout injected up to maximum 205L plus any shortfall volume in separate TAMs during Step 5A.	Expected total volume in Stage-ll range is 55L to 305L, depending on effectiveness of Stage-1 grouting "seal" achieved.
6	Injection Rate	5 lit/minute maximum, for 5A and 5B	
7	Maintaining Pressure	Target 3.0 MPa to 6.0 MPa maximum	Target pressure 3.0 to 6.0 MPa to be maintained for 2 hours by pumping grout (Item 5B).
9	Grout Controlling Criteria for "2 hours holding period"	Condition / Action	Pressure shall be monitored at circuits inlets and outlets
		A. Injected grout volume < 305L and 3.0 to 6.0 MPa pressure being maintained. (Stage-3 is not necessary). — Stop grouting at 2 hours, then locked- off inlet and outlet valves on circuits then disconnect pump.	
		B. 305L grout injected, 3.0 to 6.0 MPa pressures not being maintained (need to — Stop injection at time when 1st batch grout is still flushable (viscosity <30 sec). Flush all	

Sl. No	Items	Details		Remarks
		do Stage-3 grouting in due course).	circuits then locked- off (Remember to crack when Stage-II grout achieves "initial set").	

VI. REVIEW AND CONCLUSION:

Bored cast in situ pile of 1500mm dia of 52 mtr depth (Designed vertical load capacity of pile considered 575Ton)) in alluvial soil strata (N value of 20 to 40)was proposed . Bored cast in situ Pile was constructed by suitable Hydraulic Rotary Rig as per Indian standard codes also while execution, care was taken on Bentonite solution , cleaning bore holes by cleaning bucket on completion of boring , air flushing etc in order to get good quality of pile and to achieve theoretical capacity.

After review of above load test and In order to construct sustainable pile with improved capacity, Base grout pile was proposed in similar pile dia and length. Pile with base grout by Tube Manchette (TAM) method has implemented while casting and grouting of pile. Considering Static vertical initial load test (1400Ton) result, Base grout pile was accepted for whole bridge foundation of 136 nos.

Pile-base post-grouting is a method in which cement grout is injected into the base of the pile through grouting pipes after the strength of the concrete reaches a certain value to strength. The roles of grouting are to eliminate the influence of the technological defects of bored piles, to recover the bearing capacities of strata, and to improve the bearing capacities of piles. Based on test results of the bearing capacity, side frictional resistance, and base resistance of piles before and after grouting, post-grouting was found to have an obvious role in improving the quality, bearing capacity, and load transfer characteristics of the piles. The results of this case study can be applied and consider while designing bridge pile foundations and in Indian Standard codes considering results of economics benefit and sustainable foundation technique.

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