Construction of Upstream Coffer Dam over Jet Grouted Barrier for Teesta VI HEP, Sikkim

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ABSTRACT

The balance works at the Teesta VI Hydro Electric Power Project requires construction of the reinforced diaphragm wall along with watertight upstream coffer dam construction towards the right embankment of the existing barrage. The soil profile at the barrage location is mainly made of large sized boulders and river born material deposited over a period. The subsoil consisting of boulders to be drilled to depths of 36m below ground level for installation of Jet Grouted Columns. Trails columns are installed before start of the main works of diameter 1.4m, 1.6 & 1.8m to establish the parameters of the main works. The jet grouted columns are installed to create a watertight barrier on the upstream side beneath the cofferdam for contraction of the diaphragm and protect the barrage from the underground seepages. Symmetric predrilling with air driven DTH and casing OD of 152mm and ID 133mm casing are used for drilling. Dulex Double Water system (W/B) was used for the installation of Jet grouting columns. This paper discusses the installation of the trail jet grouting columns and execution of the main works through the boulder soil profile in the lower Himalayan regions.

Keywords: Jet grouting, Trial Columns, Boulder strata, alluvial soil formation.

1 Introduction

The construction of the upstream coffer dam at Teesta Stage – VI Hydro Electric Project requires installation of Jet Grouting Columns. The river born material are mainly cobbles and boulders to depths of 35-45m below the existing bed level of the river. Among the various ground improvement solutions proposed Jet grouted Columns are most preferred technique of sealing the ground under such high perforations. However, for the establishing the efficiency of Jet Grout column we needed to execute Trial shaft by means of overlapping jet grouted columns keeping the same parameters as applied for the production columns of the jet grout curtain or main works. A total of 12 nos. of jet grout column distributed at a circle with an equal spacing have been executed (Fig.1). Toe elevation of these columns was at 327 MSL, top elevation was at 342 MSL. Additionally in the middle portion of shaft a plug consisting of 7 nos. jet grout columns have been executed from 326.5 MSL to 331.5 MSL. Based upon jet grouting trial test, commencement of main Jet grouting works Specifying that Phase 03 of jet grouting trials to be executed in parallel of Main Jet grouting works. The work which shall outline the overall execution as an outcome of jet grouting trials, safety, quality, access, storage, distribution and measures to be implemented throughout the works.

2 Execution of Shaft

Pre-drilling in designated column locations was executed, thereafter the jetting in same pre-drilled hole with the same jetting parameters as main jet grout curtain first 12 nos. of column in the periphery of shaft were jetted and after finishing all outer columns, the inner plug columns were jetted.

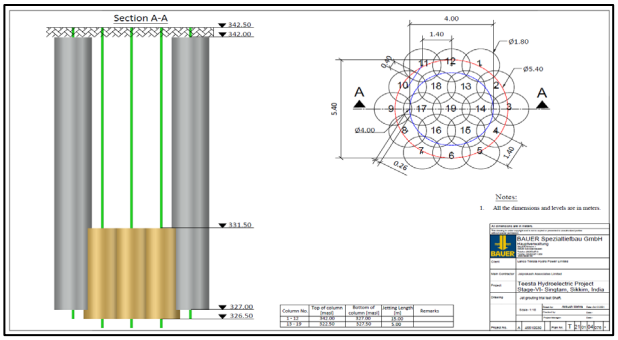

Fig. 1. Showing the Jetting sequence and jetting Depth of Trail shaft s

Fig. 2. Excavation of Shaft

After completion of all columns, the shaft was left for a period of 15-20 days for the strengthening of the jet grout columns installed. Thereafter excavation started from EL 343.0 m level (Fig. 2). After the completion of jet grouting in shaft, 2 nos. of observation hole were drilled up to the same bottom level of shaft i.e., EL 327.0m at a 4m and 8 m from the edge of shaft respectively in one alignment for the monitoring of the ground water level. After the completion of drilling activity, perforated pipes were installed in the drill hole for the ground water monitoring.

Fig. 3a. Perforated Pipes for Observation Bore Hole

Fig 3b. Installation of perforated pipe

3 Observations on the Seepage

As per visual inspection seen in Figure 4 during excavation of shaft it was found that there was no seepage of ground water through jet grout columns even the excavation of shaft up to EL 336.0 m that means the grout columns are overlapped properly and curtain is acting like seepage barrier structure. In the initial stages the ground water level was observed during drilling of main jet grout columns in phase-1 at 340.0 MSL to 341.0 MSL through the observation borehole with water detection sensors installed using the perforated pipes (Fig. 3). Considering that water level as a reference water level is justified, because the location of Trial shaft is very near to phase 1. It was found that the ground water level is fluctuating between

EL 341.0 m to EL 339.0 m in both observations bore hole during the excavation of the Trial shaft (Figs 4 & 5). The actual excavation of the shaft post installation of the jet grouted columns installed for the Trails is as shown in the Figure 6.

Fig. 4. Visual Inspection of Seepage

Figs. 5. Observation of GWT in observation bore hole with water detecting sensor

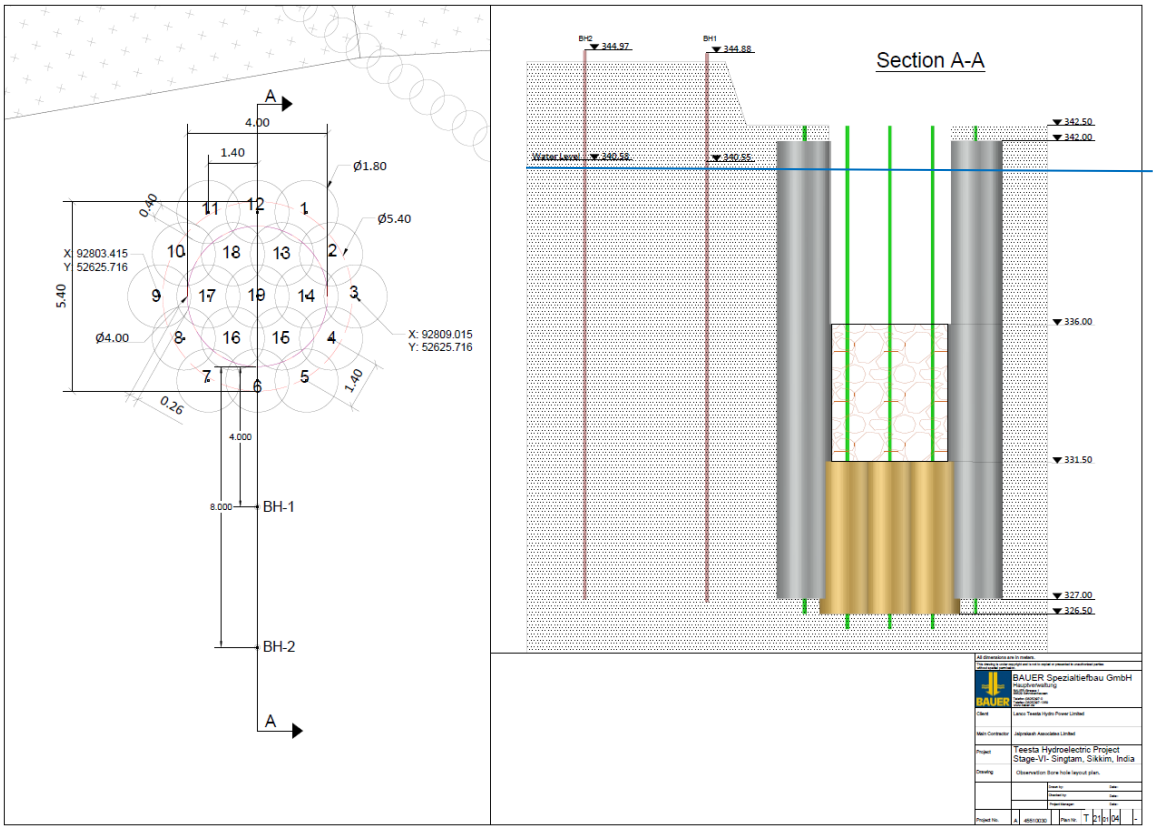

Fig. 6. Current Situation of Excavation Level in Trial shaft

4 Installation of Jet Grouted Columns for Main Works

Post the installation of the Jet grouted columns and observing the seepage conditions the columns for the main works are installed. The scope of works to be executed consists of creating a cut-off wall by means of a single row of jet grouting columns for the upstream coffer dam. Our target parameters for main Jet grouting works as an outcome of jet grouting trial campaign are as shown in Table 1.

Table 1: Summary of the execution parameters

Target Diameter (m)	1.80
Design spacing(m)	1.40
Required Specific Energy (MJ/m3)	35
Required Energy x meter (MJ/m)	88
Required Grout Vol (Litre/m)	1.260
Assumed Grout Vol (Litre/m)	1.300
Assumed flow rate (Litre/min)	360
Jet time per meter (min/m)	3.5
Time per 4 cm step (sec)	8.4
Pressure of the grout (MPa)	40
Revolutions per minute (RPM)	6 – 8
Water / Cement ratio	1.0 + 2 - 5% Bentonite
Air pressure / Air flow	12-14 bar, 10 - 15m³/min
Cement	PPC as per IS 1489-2015
Bentonite	Sodium based Bentonite power

Other Construction Materials required for the works in general locally available materials are used, as long as it meets with the technical specifications the general & special conditions of the contract and applicable standards. The final properties and dimensions of all materials need to be jointly confirmed with the Client.

5 Plant and Equipments

The key plant and equipment for the main JG works are shown in Table 2. Figure 7 diagram illustrates typical set up and arrangement of key plant and equipment for the JG works.

Fig. 7 Equipment setup at site

Table 2: List of the Main JG Equipment

Predrilling rig	No.1 Casagrande C6 type or Equivalent
Jetting Rig	No.1 BG 30 with JG Kit
High Pressure Pump	No. 1 Metax MP7 triplex HP pump
Mixer	No. 1 MAT SCC 40K or Tecniwell

Hose Mud Pump	No. 2 MAT HP 50
Inclinometer	No. 2 SAAF scan on hose reel
Agitation tank	No. 2 Bauer Make
Bentonite Mixer plant	No. 01 of BM 2000

6 Jet Grouting Methodologies

There are 4 methods of Jet grouting as shown in Table 3 and the selection of the technique depends on the prevailing soil conditions, scope of the work and technical specifications. The chosen method for this project is the BL method (Fig. 8) of high pressure cutting with cement slurry and air assistance.

Table 3: Jet Grouting Methods

Definition of BAUER		**Definition according to EN 12716**
B	High pressure cutting with cement slurry	Single System
BL	High pressure cutting with cement slurry and air assistance	Double (Air) System
WB	High pressure cutting with water and injection of cement slurry at low pressure	Double (Water) System
WLB	High pressure with water under air assistance and injection of cement slurry at low pressure	Triple System

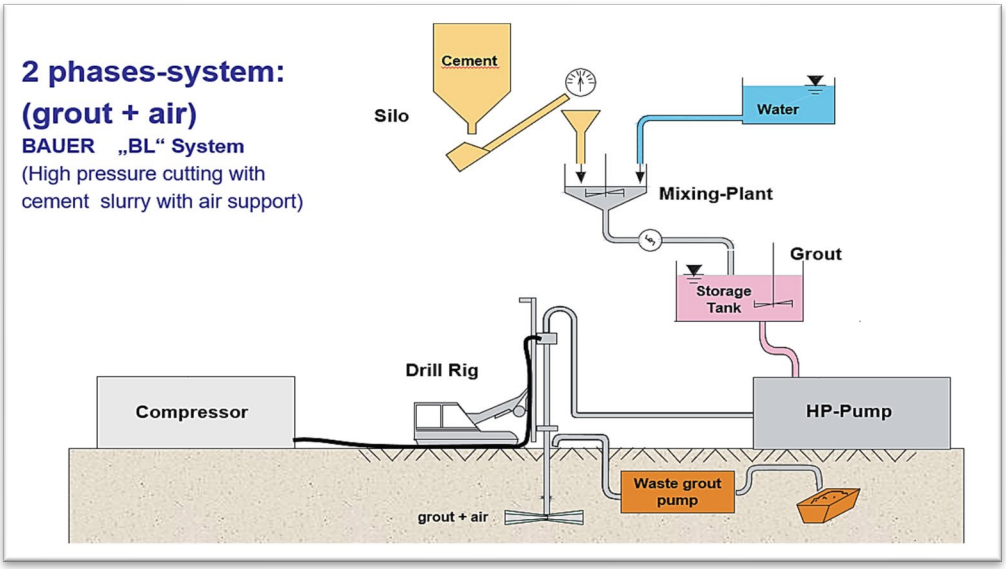

Fig. 8 Phase system (Grout + Air)

7 Procedure of Installation of Jet grouting Works

The alignment of the installation of Jet Grouting for Main works, the working platform levels are at different levels. As a result, the works have to executed in 4 phases to ensure proper bonding between the jet grouted columns. The construction of Jet grouting columns involves the

- Setting out JG curtain column centre points using coordinate system and a total station.
- Mobilization of predrilling rig Casagrande C6 or Equivalent), Jetting rig (BG30), compressor unit, drilling tools and accessories, slurry lines etc.
- Predrilling and Redrilling for jetting of column.

- Performing quality control tests on Production JG columns and submission of test reports.

7.1 Setting out Jet columns locations

The coordinates of JG column points will be calculated from setting out data provided in the construction drawing. The JG column points will be fixed using Total Station.

7.2 Predrilling of hole

Due to the difficult nature of the soils to be drilled, separate per-drill with an air driven DTH hammer was required to be drilled. Predrilling was performed using a Symmetrix system with an air driven DTH hammer, with outer casing D 152 mm and inner rods D. 90 mm. The Casing diameter was 152 mm, Pilot bit (hole) diameter 164 mm (Fig. 9).

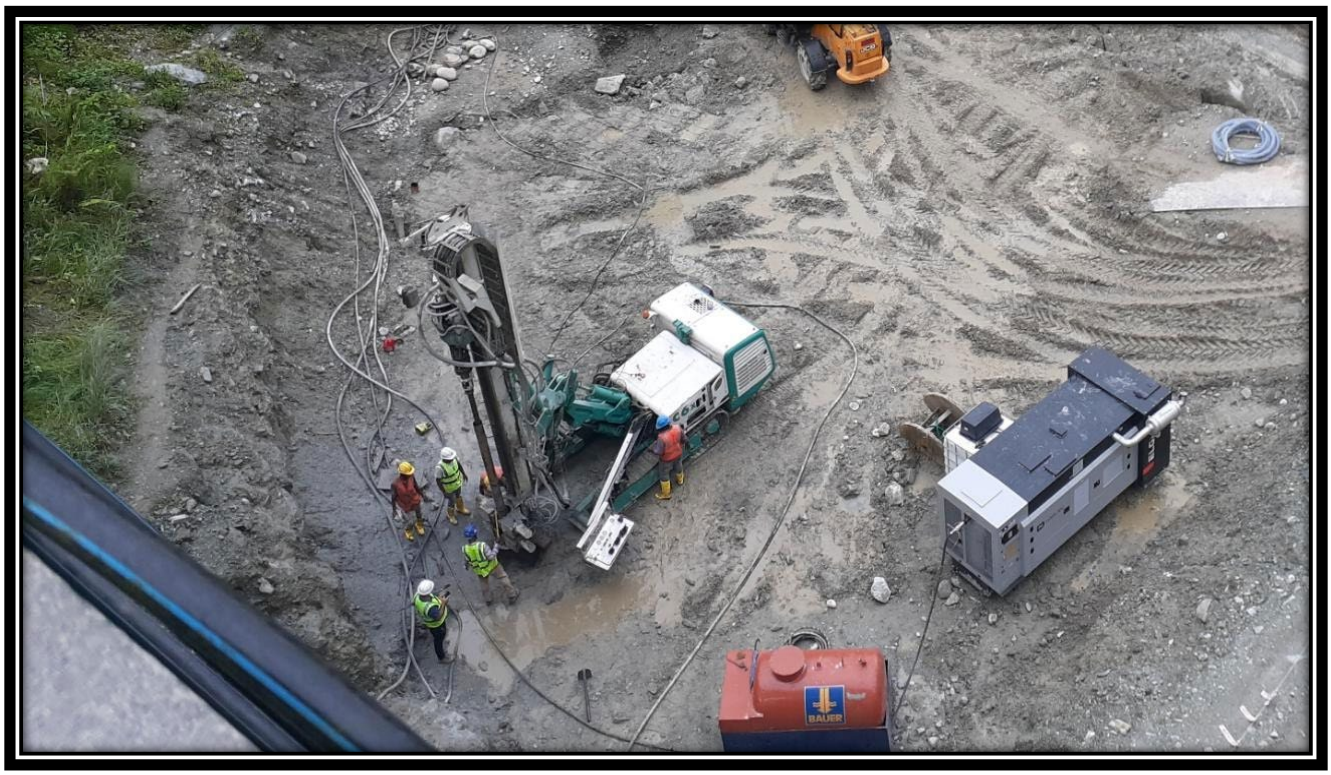

Fig. 9 Predrilling of the Holes in the Boulder Strata

7.3 Redrilling and Jetting of column

Redrilling and Jetting of production columns involves Rotary drilling will be done inside the predrilled hole with 114 mm jet grouting rods equipped with a 160 mm reamer (Fig. 10). Water or a thin cement grout is used as flushing means for redrilling. Slow increase of water/grout and air pressure to planned values to ensure the flushing is complete. Then start of jetting, i.e. continuous lifting of the drill string at the predefined withdrawal rate and RPM. Continue lifting of the drill string up to the specified elevation. Once the planned top of column is achieved, stopping the high-pressure jetting and reduction of grout and air pressure to the minimum, to avoid clogging. Extraction of the drill string with continuous grout pumping at minimum pressure to ensure that grout still appears at the top of the borehole.

Fig. 10 Redrilling for Jet Grouting and Predrilling of the Holes in the Boulder Strata along the alignment

8 Quality

All operations are carried out in an organized and systematic manner, ensuring traceability, and monitoring of the various components of the project, to provide a competently completed end product.

8.1 Quality Control

To ensure that the construction procedure follows the requirements of the specifications and standards stipulated for the execution of main Jet grouting works.

8.2 Quality Assurance and forms of quality control and recording

The quality assurance for the controls during predrilling works, jetting works, testing of bentonite and grout slurry, sampling and testing of grout cubes are carried and recorded. Any unexpected drilling condition encountered are noted briefly in the records and brought to the attention immediately.

9 Conclusion

The presence of the jet grouting curtain of shaft, was tested for any potential to percolations under shaft under water height of 4m. However due to the presence of jet grout curtain of shaft, it is evident the seepage is not observed to a greater extent, and we could observe very negligible water seepage found with a permeability of **$3.0856^{*}\ 10^{-7}$ m/s** through disturbed rock boulder embedded along with the grouted wall of shaft during dismantling. After providing the lateral support system when further excavation commenced and was able to chip it with breakers due to its hardness and strength. Further dismantling was disturbing the excavation resulted in damaging of the Cementous grout wall due to deep embedment inside grout curtain of shaft and this will further damage the shaft by breaking the Cementous bond between the rock boulder and grout and may lead to seepage inside the shaft. This tendency is additionally intensified by the inevitable vibrations exerted by hydraulic hammers. Such kind of scenario would not reflect the in-situ

condition of the jet grouted curtain. So, it was decided to suspend the dismantling operation and continue the observation of seepage induced by the presence of water table at 4.0-meter head difference. The visual inspection of the shaft walls accompanying the excavation works show a homogeneous treatment of the ground. No imperfections or discontinuities could be observed. The following are the main observations.

- Both homogeneity of treatment and low permeability values confirm the plausibility of the applied combination of jet grouting parameters and spacing.
- After theoretical calculation it has been found that the permeability of jet grout curtain of shaft is **$3.085*10^{-7}$ m/s** respectively 0.3 lit/sec and 1000 m^2 wet area which is very less taking into account the difficult geology and shall be considered as an effective seepage barrier with better efficacy.
- We can also correlate this observation to our main jet grout curtain and this observation provides evidence of better efficacy as a seepage barrier and resembles the efficiency of main jet grout curtain functionality.

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