A Review on Baglihar Hydroelectric Project

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***Abstract*—**The 900 MW Baglihar Hydro Electric Project (BHEP) constructed on river Chenab in state of Jammu and Kashmir is one of finest examples of shear application of various departments of engineering. Lying in the mountainous and rugged terrain of the middle Himalayas, BHEP has a major impact in the generation of the power not only for the state but also for our country. Construction of such a mega project involves numerous activities, which need to be properly planned before their execution, so it is necessary to plan the sequence, construction methodology and equipment for each activity so that the project may be completed within time.This paper deals with the construction details, planning and methodology adopted for this project with special reference to the civil engineering works.

Keywords—BHEP, HRT, TRT, MVA, EL, GIS

I. INTRODUCTION

The advantages of a hydroelectric project are well known to world. The Jammu and Kashmir State being a mountainous area with a number of perennial streams and rivers, naturally abounds in vast potential of Hydro-power.The Baglihar Hydroelectric Project is divided into 2 stages. The stage-I was commissioned in 2008 and the stage-II is still under construction. Baglihar Hydro-Electric Project stage-I comprises construction of a 143.0 m high concrete gravity dam on river Chenab, Power Intake structure (2×430 cumec capacity to feed both stages), about 2.01 km long and 10.15 m diameter Head Race Tunnel, 27.5 m dia. and 77.0 m high restricted orifice type Upstream Surge Shaft, three Pressure Shafts, an underground Power House (3×150 MW installed capacity), a Downstream Collection Gallery and 130 m long Tail Race Tunnel (varying from 8.8 m at collection gallery end to 10 m at its outfall end). Three Pressure Shafts off-take at the bottom of Surge Shaft to feed three turbines installed in the Power House Cavity. The Tail Race tunnel of Stage-I Project is free flowing. Baglihar Hydro-Electric Project stage-II comprises a Power Intake (already constructed with Stage-I works), about 1889 m long and 10.15 m dia. Head Race Tunnel, 27.5 m dia. restricted orifice type Upstream Surge Shaft, three Pressure Shafts, an underground Power House, a Downstream Surge Gallery and 10.15 m dia. 342.6 m long Tail Race Tunnel.

Electro-mechanical components of the project include 6 150MW Francis turbines of which 3 are installed in stage-I and other 3 are to be installed in stage-II. The generators used are 168MVA vertical shaft synchronous generators and the transformers are 60 MVA single phase transformers. The type of Cranes used are 150 ton EOT cranes.

II. CONSTRUCTION METHODS

II.1 Excavation

The process of removing the part of Earth like soil, rocks etc. for the purpose of construction is called excavation. Excavation of rock chamber generally starts with a horizontal tunnel at the top of the area which has to be excavated and continues down step by step. The portion of rock is excavated by process of drilling and blasting, which progresses in several headings. A pattern of holes is drilled into the rock and then these are filled with explosives which are then detonated. The explosion collapses the rock and this lengthens the distance of the tunnel face. The shape of the tunnel is achieved by carefully calculating the position and the depth of each hole which has to be drilled. The process of drilling and blasting is repeated until the required length of the tunnel is reached. A vertical bore hole is drilled in the ground to get the information about the sub-soil strata or to create a space for the explosives. Ingersoll rand (IOR), drilling rod, Chicago Pneumatic (CSR086), rocket boomer, anchor rod etc. are the common equipment's that are used in the process of boring.Gelatine or dynamite, detonator, hollow plastic rods are commonly used equipment's in blasting.

II.2 Shotcrete Lining

It is a technical term used to designate cement mortar applied under pressure through a nozzle on the surface of the channel.
It consists of cement and sand generally in the ratio of 1:4.
Sand is having a maximum size of 0.5cm. Larger proportions of cement are required in shotcrete as compared in cement concrete. Wire mesh reinforcement is generally used.Shotcrete lining is generally laid in a thickness of about 3.5cm.Very simply shotcrete is the term used for spraying concrete and mortar onto a surface at high velocity.
Shotcrete is a treatment applied to better surfaces, usually for one of two reasons:

1. To protect a surface which is left untreated, would fret and erode (or is already doing so). Such surfaces may be localised comprise anything up to the entire batter, depending on the circumstances.

2. To provide structural support for otherwise sound rock which is being undermined by erosion or which is unstable (due to defect orientations or degree of fracturing).

II.3 Rock Bolting

A rock bolt is a long anchor bolt which is used to stabilize rock excavations. Theyare used in construction of tunnels or rock cuts. It main purpose is to transfer theload from the unstable exterior portion of the rock to the confined and stronger and stable interior of the rock mass. Rock bolting is a primary means of rock reinforcement used to stabilize rock. Rock bolting reinforcement and support is maximized with the addition of a wire meshing system and shotcrete. Rock bolts are arranged in such a way as to transfer the load from the exterior of the rock to the stronger interior part of the rock. The distance between two rock bolts should be 1.5m to 2.15m. Rocket boomer, anchor rod, bit, Teflon or PVC pipe connected with screwed reinforcement rod, shell connected on the top of screwed reinforcement rod, square iron plate, expansion shell, and grouting pipe and air bent pipe are the common apparatus used in rock bolting. There are three major methods of anchoring the rock bolts are mechanical method, grouted method and the friction method.

II.4 Grouting

Grouting works are a significant part of these important projects, mainly in consolidation and strengthening of weak soil during tunneling excavation, ground movement control during tunneling operations, waterproofing of existing structures, preventing spreading of hazardous contaminants, foundation plate formation, re-opening of old dams and tunnels. The process of grouting involves injecting a grout material into an isolated pore or void space of unknown configuration and volume. The main use of pressure grouting is to improve the geo materials like soil and rock. The grouting can be used to strengthen and reduce the flow of water through a formation. It can also be used to rectify the faults in concrete structures or masonry structures. The various types of grouts used are Portland- Cement Grout, Clay Grouts, Asphalt Grouts and Chemical Grouts. First a hole is drilled to the bottom of the zone to be stabilized and a casing is placed to within a meter of the bottom of the hole. The casing should fit properly and may require pushing into a place. Sometimes it is driven entirely (i.e. predrilling eliminated).The grout is then pumped in until 'refusal' is achieved. The casing is then raised and pumping is repeated 4 to 5 times until ground surface is reached. Grouting can also be done in an opposite way i.e. top to bottom which has more advantages but is more expensive.

III. MAJOR COMPONENTS OF THE STAGE - II PROJECT

III.1 Dam.

A dam is a barrier that impounds water or underground streams. The Baglihar dam is a gravity dam Located across the river 'Chenab' near the Baglihar village, some 5km away from Chanderkote. Its height is 143 m, length is 363 m and width (at the base) is 136m. Road width at the top is 8m. The dam is not a solid one, but consists of 22 blocks; it has got 5 Main Spillways, 3 Chute Spillway gates and one auxiliary spillway (as shown in figure 1). The storage capacity of the reservoir is 475 million cubic meters of water. The estimated quantity of concreting performed in the dam is 25, 87,803 m^3. Based on the pond levels, the inlet level of intake has been kept at EL 821m and the peak level of spillway has been kept at an elevation of 808m.The arrangement provided for dissipation of energy consists of splitters and ledge on spillway surface. A plunge pool of 70m is provided below the spillway.

Figure 1 (Baglihar Dam)

III.2 Intake Structure

The intake structure for the Stage-II project of BHEP has been constructed along the intake structure of Stage-I project because it would have been impractical to construct it at a later stage without stopping the Stage-I Powerhouse. The Intake has been constructed on the Right Bank adjacent to Dam (as shown in figure 2). The intake has been designed for 430.0 cumec discharge. In monsoons, the river carries large quantity of sediment as bed-load and suspended load. The reservoir behind the dam will function as a sedimentation tank. The coarser sediment will, therefore, settle in the reservoir till it is silted up to the spillway crest level (El 808.0m). The inlet level of the intake has been kept at El 818.50m so that even after the silting of the reservoir up to 808.0m level, most of the bed load from the flow will be flushing out by suitable operation of the spillway gates. The level of gate sill for the intake gates has been kept further higher by 2.5m i.e. at El 821.0. The minimum pond level has been fixed at El. 836.0 m. The intake have its invert at El. 821.0 m which is 13 m above the crest of sluice spillway. With this level, sufficient cushion is available for preventing the sediment in the reservoir from entering the Head Race Tunnel. As such the water drawn by the intake will be practically sediment free even when the reservoir is silted up to the spillway crest. At the entrance of intake, trash-racks have been provided during the construction of intake of Stage-II along with the works of Stage-I.

Figure 2 (The intake structure of BHEP)

III.3 Head Race Tunnel (HRT)

Each of the intake lead to their own Head Race Tunnel (HRT). The dia. of both the HRTs are 10.15 m and these are circular in shape. These have got a Sloping Length.

It is a 2080m long concrete lined and grouted circular water conductor system which is designed to carry a discharge of 430 cumec with a maximum velocity of 5.28m/sec. It is constructed by traditional methods of drilling, blasting, mucking and concreting. The invert level of headrace tunnel at the inlet end is at El 815.350 m. Since the intake of Baglihar Hydro Electric Project Stage II is on the left side of the Head Race Tunnel of stage - I and the Surge Shaft of stage II is on the right side of the Head Race Tunnel of stage I, the Head Race Tunnel of stage II has to cross the Head Race Tunnel of stage I. The overt level of Baglihar Hydro Electric Project Stage I tunnel at the location where it is crossed by the stage - II tunnel is about 798.4 m. The Head Race Tunnel of stage - II is proposed to be kept almost horizontal up to about 50 m downstream of the crossing, so that, a clear vertical rock cover of about (815.35 - 798.34 - 1.0) = 16.006 m will be available at the crossing. The invert level of Head Race Tunnel - II at its junction with Surge Shaft is kept at EI. 775.35 m (as shown in figure 3). As such, there will be a downward slope of about 1:38 beyond the crossing of two tunnels.

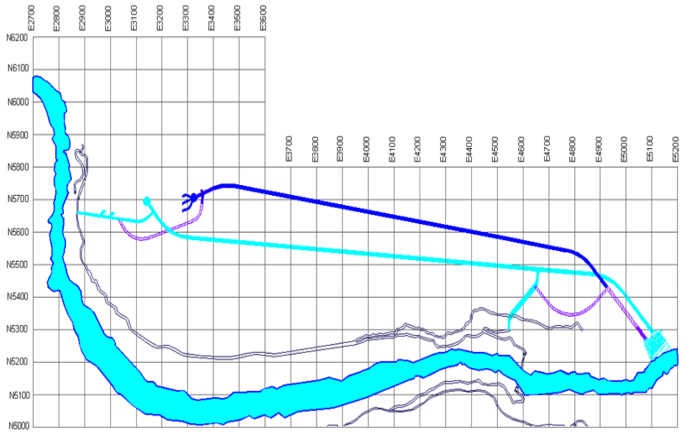

Figure 3 (Layout of HRT's)

III.4 Upstream Surge Shaft

Surge Shaft is a very important component of the whole system. Its main function is to prevent the phenomenon of 'Water Hammering'. According to the most popular theorem of Fluid Mechanics i.e. the Bernoulli's Theorem, sum total of all the energies (Potential energy+ Kinetic energy+ Pressure energy) of a fluid remains constant during its motion. Applying this to the actual problem, if we abruptly stop the flow of water from the penstock to the spiral casings, its kinetic energy becomes zero and hence either or both the potential and the pressure energy must increase. If potential is not allowed to increase, the pressure may increase to such an extent that it may damage the penstocks and gates. To prevent this, we provide an arrangement for increasing the potential energy of the fluid by the help of the Surge Shaft. Surge Shaft is a huge tank like structure with a height of 77 m and a dia. of 27.5 m. It is of Restricted Orifice Type. There are fixed wheel gates (Bonnet type) with hydraulic hoists for each pressure shaft located in Gate Chamber downstream of Surge Shaft. An opening of 6.14 m dia. is provided in the orifice slab. The approach to the roof vault at the top of surge shaft is through an approach audit cum air vent of 308m in length. A Restricted Orifice type Surge Shaft is proposed as it would be most economical and efficient for this installation. The invert level of the Head Race tunnel at inlet i.e. downstream end of intake and at the Surge Shaft junction will be El 815.35 m and El 775.35 m respectively. The plan of surge shaft is shown in figure 4.

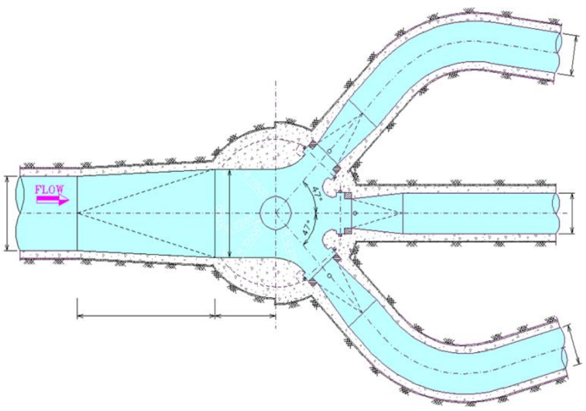

Figure 4 (Plan of Surge shaft)

III.5 Penstocks

The main purpose of penstocks is to carry the water from HRT to the turbines. Each HRT gets split up into three penstocks which lead to their respective turbines. The penstocks are circular in shape and have a dia. of 5.5 m each. These are Steel-Lined. The lengths of the three penstocks are 214.614 m, 196.435 m and 192.740 m. The material of steel liner is ASTM 537 Grad "A". The velocity of fluid inside the penstocks is 3.2 m/s. The pressure shafts have to come across a drop of 84.425m between the center line of Head Race Tunnel at junction with the surge shaft at EL 780.425 and center line of machine EL 696m. Provision of gate at the entry of penstocks is considered essential so that individual pressure shaft can be dewatered for inspection and maintenance of steel liner as also for inspection and maintenance of MIV in powerhouse, without dewatering the Headrace Tunnel. Three sets of Stop log Gates along with their hoists have been provided for isolating the Penstocks from HRT whenever, required.

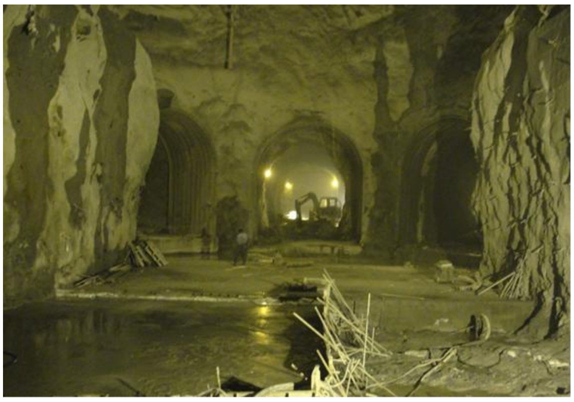

Figure 5 (Surge chamber from where HRT will differentiate into 3 Penstocks)

III.6 Powerhouse Complex

The underground cavities of machine hall and transformer hall are located on right bank of river Chenab. The machine hall cavity is 24m (W) x 50m (H) x 121m (L). It houses 3 machine bays , a 30m long service bay on east end and control building block (25m long) on the west end. The transformer hall cavern is of size 15.0m (W) x 24.5m (H) x 112.25m (L) and is parallel to powerhouse cavern. This cavern houses 10 single phase transformers (3x3 plus one spare) at EL 708.3m and gas insulated switchgear (GIS) equipment on a floor at EL 719.3m. The cables from the switchgear room have been taken to a surface pothead yard at EL 750m, through a cable tunnel of 185m length. The Machine Hall is subdivided into the following sections:

• Pump Section or Main Inlet Valve Section (MIV).

The pump section houses four cooling pumps which supply cold water for cooling the turbines and the alternators. These pumps receive the water from the Draft Tubes. After cooling is done, the hot water is sent back to the draft tubes. In order to clean the coolant (water) from different impurities, there are various strainers.

• Turbine Hall.

As the name suggests, the Turbine Hall houses the three Francis Turbines. Each turbine has got 13 blades in its Runner. The Turbines rotate in the horizontal plane at a rated speed of 187.5 rpm. Each Turbine is attached with two servomotors, each of which is connected with a Regulator Ring. The Servomotors are two phase motors which are used for controlling the opening and closing of various Gate Valves. There also are sensors which are to be used to check and hence control the turbine rpm by sending the necessary information to the Governors. The governor maintains the speed of the Turbine at its rated value if any fluctuations arise in it due to variation in load. Limit switches are present which help in detection of any faults that may develop in the gates. Vibration Sensors are also present.

• Generator Hall

The generator hall houses the three synchronous generators whose rotors are coupled with the shafts of the turbines. Generator is a device which converts mechanical shaft power to usable electrical power. Electrically it is an ideal voltage source behind the synchronous impedance. The main role of a generator is to modulate the active and the reactive powers to match the dynamic vibrations in the system based on the frequency and voltage.

III.7 Bus Duct Cable Tunnel/Switchyard

Gas Insulated Switchgears are widely employed in substation technology all over the world .Its reliability, Economic advantages and physical compactness has resulted in widespread application at all high and extra high voltage levels. GIS is based on the principle of complete enclosure of all parts such as bus bars, circuit breakers, disconnectors, earth-switches, CTs, PTs, and surge arrestors, etc. in a metallic encapsulation to protect from external environment. SF6 gas is generally used as the insulating gas. Compressed SF6 gas which has excellent insulating properties is used as the medium between energizing parts and encapsulation. Three “D” shaped bus shafts carry 16.5 KV isolated bus ducts for evacuating power from generating units to transformers. From GIS power is evacuated through cable tunnel up to pot head yard through 400 KV XPL cables for further transmission to grid. The switch yard has pots, isolators, wave traps, CVT and lightning arrestors. The GIS floor is shown in figure 6.

Figure 6 (GIS Floor)

III.8 Tail Race System

The tailrace system consists of a collection gallery of size 12.5 m (W) x 44m (H) x 75m (L), a 130m long tailrace tunnel and an outlet structure. The collection gallery also plays the role of downstream surge chamber. The draft tube gates located at the junction of draft tube tunnels with collection gallery are operated from collection gallery at EL 726m which is 10m above the roof of collection gallery. The tail race tunnel is concrete lined and is 130m long and 9m wide and meets the outfall structure at EI 700m above sea level. After the water does its work in the turbines, it is sent to its respective draft tube for the expulsion. Draft tubes are meant to convey water to the tail race at a pressure that wouldn’t cause turbulence. Draft tubes start at the bottom of the turbines, run down steeply for a height of 8 m and then slope up. The initial slope is rising in the direction of flow with roof of tube more steep for a distance of 840 m. An intermediate pier runs across the tube to cut the velocity of water .This pier has a nose liner. Double reinforcement are done in walls of the draft tube in both directions running perpendicularly. The draft tubes empty into the collection gallery at a level of 691m. The cavity size of the Collection Gallery is 75m x 12.5m x 43 m. It is meant to collect water up to a height of 27.5 to 30 m. Lining of collection gallery has been done and additional reinforcement will be done in the walls at the level of draft tube exit. It also functions as downstream surge chamber. Tail race tunnel is a 135 m long tunnel, 10 m wide and height ranging from 19 to 27.5 m. It is D-shaped meant to convey water back in to the Chenab river. The bottom of the tunnel is sloping above its direction of flow and the exit level would be 702 m. It has been bolted with rock bolts but the problems have arisen in its lining due to uneven cutting in its excavation. The TRT outfall is provided at the exit of the tail race tunnel. Hydraulic gates have been provided in order to regulate the water flow and prevent the entry of excess water in reverse direction into the TRT. The TRT outfall of stage-I is shown on figure 7.

Figure 7 (TRT Outfall of Stage-I of BHEP)

III.9 Pothead Yard

A Pothead yard of size 30 m x 65 m at an EL. of 757.0 m shall be developed in continuation of existing pothead yard for Stage-I. An extra 2.5 m wide strip of land on hill sides of the Pot Head Yard Area shall be developed for drainage purposes. Cement concrete wall having a top width of about 1.0 m shall be constructed, all around the periphery of the Pot Hard Yard Area firstly to retain earth where earth filling is required and secondly this wall will act as foundation for fencing posts.

CONCLUSION

In this paper wehave portrayed a brief account on how the functioning of hydroelectric project takes place especially when we consider it’s various components altogether. Our aforementioned observations and studies in this regard result into satisfactory analysis of water movement for the electricity production which commences from Head Race Tunnel (HRT) and ends at Tail Race Tunnel (TRT). The advancement of water through Surge Shaft, Penstocks including the Pressure shafts create a gravitational pull which increases its kinetic energy to a mammoth amount exactly equivalent to the desired quantity in order to strike the turbine radially. The precision with which these sections (HRT, TRT, Surge Shaft, etc.) are designed and constructed develops minimum loss of water hence yielding optimum value of head required to carry out all operations with relative ease. The combination of various fields of engineering in this very project(BHEP) results into formation of high quality of energy with economy which will ultimately benefit the state as well as the whole country.

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