A Sculpture in Rock to Convey Water

Dr P.V.Chandramohan and L. Prabahar

Abstract

The government of Andhra Pradhesh is going in for lift irrigation in big way. Lift-2 of Rajiv (Bheema) Lift Irrigation Scheme (Stages 1 & 2) is being done by Navayuga Engineering Company Ltd. The scheme envisages conveyance of water through a horizontal distance of about 10km and vertical lift of 80m, in two stages. The horizontal conveyance is done through tunnels and canals while high lift pumps are used pump up water through delivery mains. During pumping, sudden shut down of pumps due to power failure can create adverse transients. These are to be tackled by suitable specialized means.

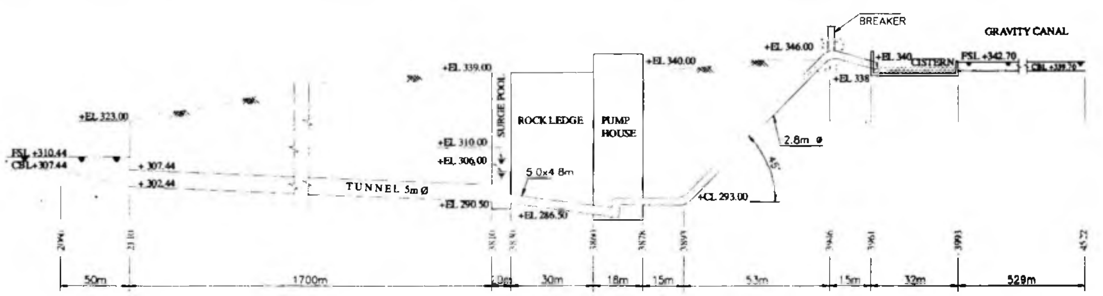
Introduction

In many places in the State of Andhra Pradhesh, the terrain is undulating. The rain water that falls on it, flows into valleys and rivers within a short time. To get this water back to the highlands for cultivation, this water has to be pumped up. Lifting and conveying this water to these locations is Lift Irrigation. But when the amount of water to be lifted is high, the project assumes gigantic proportions. The government of Andhra Pradesh is going in for lift irrigation projects in a big way. Lift-2 of the Rajiv (Bheema) Lift Irrigation Scheme (Stages 1 & 2) is one such project. The design and construction of the project is being done by Navayuga Engineering Company Ltd.

Layout of Stage-1

The intake of the main scheme is at the Okachettivagu balancing reservoir. The water is initially led through a canal two kilometers long. The intake of the present project is at the end of the canal. A lay out of Stage-1 is given below. Please refer to Fig 1 & 2

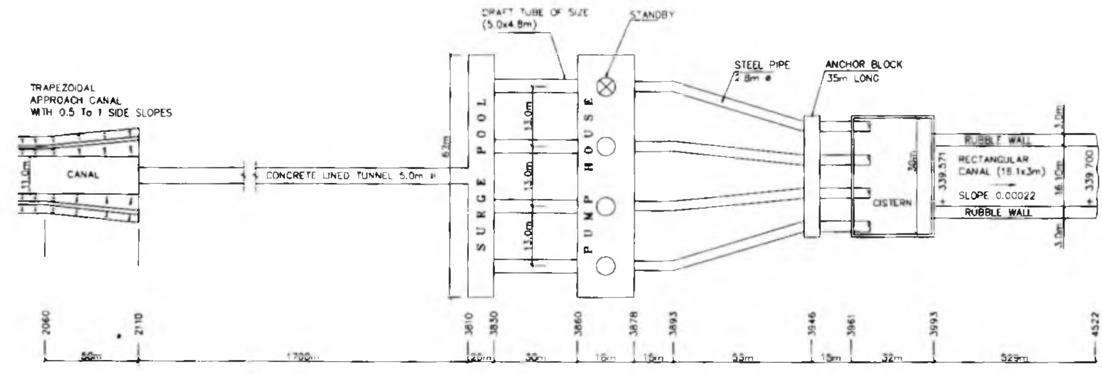
The scheme has to convey 63.72 cumecs of water through a horizontal distance of 2500m, lifting it through 38 metres in the process. From the intake ramp, a 1700m long tunnel conveys water to a surge pool. The tunnel is blasted through hard granite rock, the over burden varying from 18 to 42m. The intake pool is of size 62mx20m in plan and 50m deep. At a distance of 30m beyond the pool is the pump house. This is a similar structure of size 62mx18m with a depth of 54m. Three Francis turbine pumps each with a motor rating of 12MW and one as standby will be installed in the pump house. The surge pool is connected to the pumps through draft tubes dug out through the rock ledge separating the pool and the pump house.



Stage - 1 Elevation

Fig. 1. Elevation of Stage-1

Navayuga Engineering Company Ltd. 1259, Lakshmi Towers, Road #36, Jubilee Hills, Hyderabad – 500 033 (Email : pvcmohan@gmail.com)



Stage – 1 Plan

Fig. 2. Plan of Stage-1

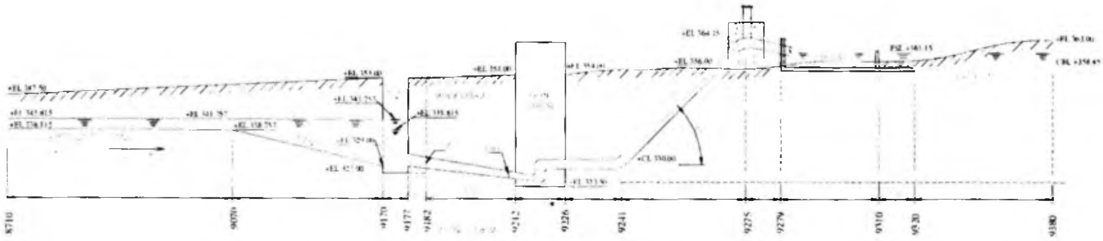
Delivery mains, 2800mm in diameter, fabricated out of pressure vessel quality steel plates are laid from the pumps to a cistern. As can be seen from the figure, these mains are to be laid through tunnels partly horizontal and then inclined at 45°. The delivery mains droop into a cistern through a goose neck. The cistern is rectangular in plan. It will dissipate the energy of the discharged water. Water then overflows a weir and is let into a gravity canal to proceed to Stage-2. Some lateral diversion is carried out during this conveyance.

3 Lay out of Stage-2

The Stage-2 of the scheme follows after a connecting canal of 4000m. From this canal, a part of the water is laterally diverted to some areas. Please refer fig 3 & 4. Stage-2 envisages conveyance of 32.28 cumecs of water through a horizontal distance of 250m, lifting it vertically through 22m. In this case, the approach ramp is directly connected to the surge pool. The surge pool is 54mx15m and 26m deep. The rock ledge is of same length of 30m. The pump house is of 54mx14m size with a depth of 31m. There will be three pumps + one standby here. The pumps are of Francis Turbine type and would have a motor rating of 4MW each. Delivery mains are aligned in the same manner as in Stage-1 but have a lower diameter of 2.00m. The scope of the project to be executed by Navayuga Engineering Company Ltd ends with the cistern to which the mains discharge.

Contrasting similarities

As can be visualized, this project is similar to but the reverse of a hydro-electric power station. Primarily, in a power station, electricity is generated from the potential energy of water flowing down from high elevation. In lift irrigation project, electricity is utilized to lift water to a higher elevation. In a power station, turbines are moved by water pressure. This rotates the generators to produce electricity. Here, electricity rotates the motor coupled to impellors of pumps and



Stage – 2 Elevation

Fig. 3. Elevation of Stage-2

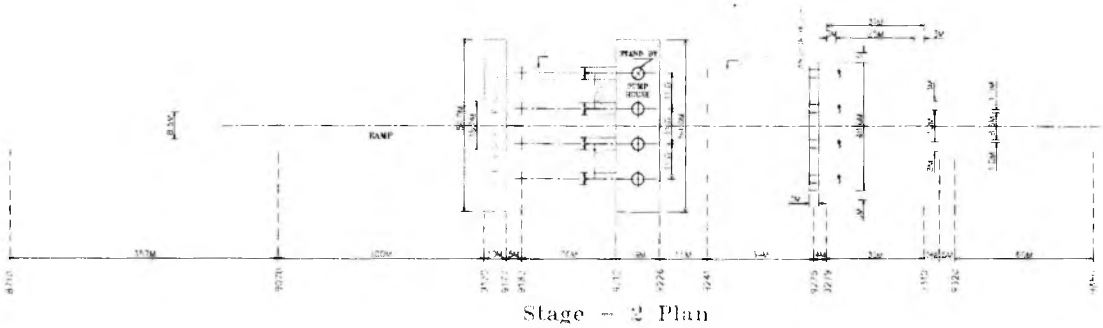


Fig. 4. Plan of Stage-2

water is lifted up. In a power station, water comes down through penstocks. In a pumping station, it goes up through delivery mains. Both are similar in nature except the former is subjected to sharp water hammer pressures. The tail water side of a power station is the reverse of the intake side of a pumping station.

Surge and backflow

The surge pool serves two purposes. During starting up of the pumps, there will be a lag in acceleration of water to feed the intake requirement of the pumps. The surge pool will act as a buffer. This is not very drastic as only one pump can be started at a time. Secondly, in the event of a power failure, all the pumps shut down simultaneously. The inflow through the tunnel is stopped suddenly. The momentum of the incoming water in the tunnel will manifest in the form of a rise in water level in the surge pool. Besides, the water in the delivery mains flow back through the pumps and draft tubes into the surge pool resulting in a rise in water level. The total water level rise will have to be accommodated by the surge pool. The pool size will largely depend on the volume of water in the intake tunnel. Siphon breaking flap valves are provided at the top most point of the mains to prevent the water in the cistern from flowing back into the pool at power failure.

A scaled down, instrumented hydraulic model was made. Experiments were conducted to observe the above factors. It was found that the model was working satisfactorily.

Drilling of tunnel shaft

The drawdown between the water levels at the intake ramp and the pool is the head for the flow through the tunnel. The cross section of the tunnel is proportioned on this basis. The available head was 3.44m. The most efficient shape for pressure flow is a circular section. The diameter was arrived at as 5.0m. But from execution angle, a D-shaped section was preferred. This was due to the fact that removal of the blasted muck from the tunnel had to be carried out through wheeled/tracked carriers and would require a flat bottom surface. The equivalent size of a D-shaped section would have been 4.7m. But to facilitate two vehicles to cross each other, 5m had to be retained. This way, excavation was more but faster progress could be achieved. At the intake, the depth of tunnel is less. A sloping ramp was made through the approach ramp and back for the movement of vehicles carrying muck from the tunnel. This was the first tunneling point. But for a length of 1700m, with the available time frame, another working point was required. A point near the surge pool was selected. Here, the tunnel is deeper as it joins the pool at the bottom. With a slope of 1 in 10, the ADDIT would have a length of 500m, 280m of which would be in tunnel form. Like wise, the ramp for removal of muck from the deeper surge pool is also quite long. So, the addit for the tunnel was branched off from the ramp to the surge pool. Excavation presented unpleasant surprises. The rock stratum was anything but continuous. It did not follow the one indicated by the borings. As the work on the ramp before the 'addit' proceeded, the rock stratum at that depth suddenly ceased to exist. Tunneling would have been impossible. So, the excavation was set off in another direction after retracing some distance backward. More than any reasoning, hope was the only guide. One cycle including marking, drilling, loading, blasting, de-fuming and scaling lasted 9 hours. The progress achieved during one cycle was about 2 metres. There were difficulties when quartizite was encountered in the tunnel. The progress was slowed down. Generally, the stratum consisted of very hard granite which also affected the progress.

Excavation for surge pool

Physically, the surge pool is a massive pit with vertical face, to be dug out into the top soil and the rock below. Removal of muck by lifting was considered but as the surface of the rock was found to vary sharply around the pool, installation of cranes for lifting would be difficult. So, it was decided to remove maximum possible muck through a ramp. The additional excavation for the long ramp was considerable and the depth to which the ramp could go was limited. Lifting had to be resorted to beyond a depth. But, as the tunneling from the adit reached the pool, blasting and mucking could be opened up from there. An output of $300m^3$/day was achieved.

Excavation for pump house

The pump house required a deeper excavation. The rock level at this location was generally high. It was decided to employ a combination of 'ramp' and 'lift' here as in the surge pool. Up to a middle depth, the removal of material was done through vehicles plying on the ramp. This was faster. But below this depth, the material would be lifted by cantilever gantry cranes running on rails. The excavation of the surge pool would reach the bottom earlier. Excavation of the draft tubes from there could be initiated and would reach the pump house before the pump house excavation reaches the bottom. So, blasting and removal from the bottom of the pump house can proceed through the draft tubes and through the surge pool.

Drilling delivery main shafts

Another difficult excavation is that of the delivery mains. The major portion is inclined at 45°. Blasting and removing the muck through a 45° shaft requires special kind of plant. A hauling plant was specially designed and assembled at site. Four shafts were to be made. Unlike in the tunnel, the section is circular and the diameter is 3.5m only. Initially, mucking was done from the top manually. Later, rails were laid in the tunnel and muck was carried in trolleys hauled by a 5t winch. The trolleys had bottom opening arrangements to dump the muck directly into trucks. Two winches were mobilized for four shafts. The bottom horizontal portion and a small inclined portion were tackled from the pump house. So, mucking from the top was done using the hauling arrangements while at the other end at the bottom manual mucking was resorted to. Both advances met midway. The project is on its way to commissioning by the end of next year.

Execution at Stage-2

The Stage-2 warranted a different methodology. There is no intake tunnel here. A 20 metre deep canal with side slopes had to be excavated. Mucking had to be through ramps. The approach ramp acts as the mucking ramp for the surge pool. The pump house required ramps for excavation. But the depth here is much less than in Stage-1. Besides, draft tubes drilled in from the surge pool would reach the bottom of the pump house much earlier facilitating blasting and mucking through them. This would be a bonus. Here also, the most difficult job was the 45° holes for the delivery mains. The diameter of the holes is only 3m. Incidentally, winches for hauling the muck up were not ready initially. So, the lifting was done manually. This was a slow process.

Photo. 1. The intake tunnel


Photo. 2. The draft tube


Photo. 3. The Pump house


Photo. 4. Excavation of surge pool


Photo. 5. 45° Shaft for delivery main

Photo. 6. Multiple shafts for delivery main

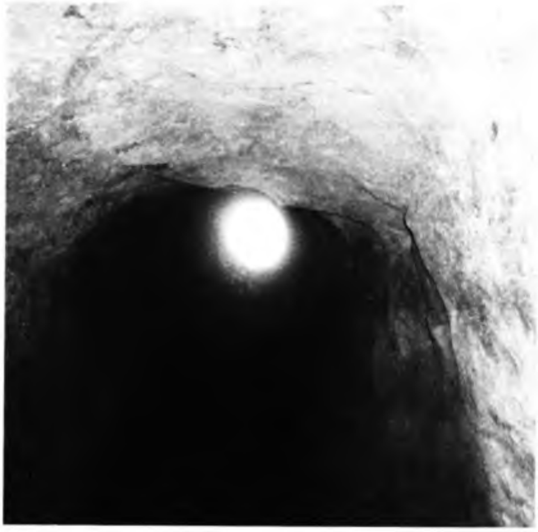


Photo. 7. Delivery main shaft

Photo. 8. View from inside the tunnel

Photo. 9. Multiple Draft tubes

Photo. 10. Draft tube right through

Photo. 11. Lining work in darkness

Photo. 12. Mucking through draft tube


Photo. 13. Draft tube face


Photo. 14. Hauling arrangement

Conclusion

The layering of soil and rock was an unpredictable phenomenon. The quality of rock is important in many ways. Hard rock is required for the excavation to be self supporting. Weak rock enables high production in excavation but entails delays from putting up supports and rock bolts. A hard rock result in low speed of excavation as blasting through them is slow. In under ground works in the rock media, unpleasant surprises are round the corner. One has to keep one's fingers crossed and be prepared for tackling the situations. Mobilisation of the right machinery and co-ordination between various activities is the key to the successful execution of the project.