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RANGANADI DAM : A SUCCESS STORY OF FOOLPROOF PLANNING AND SPEEDY CONSTRUCTION

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ABSTRACT

Hydro Power and water resource projects are the public funded: high cost structures located at strategically sensitive remote and inaccessible sites. A large number of such projects have been constructed and/or are under process of construction to fulfilling the power and irrigation demand of the country. This is a very recent construction phenomenon undertaken in the post-Independence era. The construction involves poor or hostile geological conditions and unforeseen logistic and social/political eventualities. The paper gives an overview of the recently completed Ranganadi Project at Arunachal Pradesh, India, owing its ownership to North Eastern Electric Power Corporation. Out of the total estimated hydropower potential of approximate 30000 MW only 7-8% of it has so far been harnessed. Ranganadi HE Project situated in Arunachal Pradesh was planned to harness the total water potentials of the river which later terminates into the mighty Brahmaputra river.

The paper focuses on the process of location planning, infrastructure execution, the coffer dam construction, and the challenges faced and solutions adopted during the construction. The equal thrust is given to the innovations used in the construction methods and the suitability of the equipments used.

1. INTRODUCTION

Ranganadi Dam Project was a rare success story applying rarest kind of innovative experiments and most creative managerial maneuvers to make it an exceptional success. However, this success story could never see the light of the printed world. The project site known as zero is connected only by road and has no other train or air communication. The road to the project crosses the NH-52. The village housing the project is known as Yazali from where the only rail and air connection is at North Lakhimpur, A city located in Assam.

The selection of the project for the present study hinges on the fact that such an engineering success stories has yet to be repeated in Arunachal Pradesh.

The following structures were constructed in the first phase to generate 405 MW power through its Power House located at Dikrong.

1. Concrete diversion dam 68m in height and 359.5m long.
2. 10 km long Head Race Tunnel, 6.8 m dia, horseshoe shaped.
3. Surge Shaft, 25 m dia up to first 25m; and then 16m dia up to 100 m deep.
4. Pressure Tunnel (Steel Lined), 5.8 m dia, and 1045 m long.
5. One surface powerhouse of installed capacity of 3 x 135 MW = 405 MW.

2. GEOLOGY

The project area lies in the Shivalik and Archaean Eon. The Gondavana; crust which is thrusted over by Archaeans, forms the rock composition of shales, sand stones, and acid phylites, intersected with respective coal bends at places. The Shivalik comprises sand stones with dry bends: whereas the Archaean system comprises mainly gneisses and schists. The rock cover over the dam foundation is mainly of shale and sandstone.

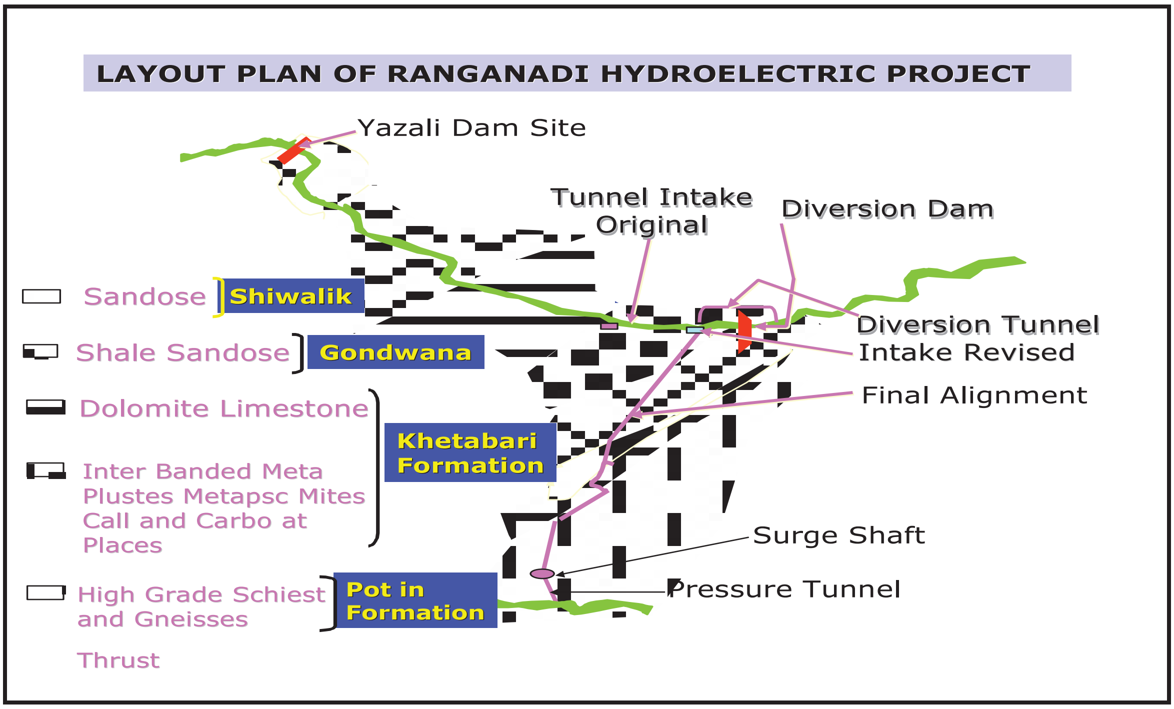

Fig. 1 : Geological details of the Project area

3. CONSTRUCTION PLANNING

The quantum of work involved was huge and to be completed in a time-bound manner, with an effective method of construction of coffer dam. Excavation, production and placing of concrete had to be thought of and meticulously planned. As the work had to be carried out on both the banks, it was decided to opt CK-170 excavator and 25T Tippers for carrying out 9,52,000 m^3 excavation. The entire establishment including the crushing plant, batching plant, cableways was planned to be set up at the left bank.

The crushing plant inclusive of primary, secondary and tertiary crushers and sand units for producing the maximum 1200 m^3/day, was established to meet the maximum concrete requirement.

For transporting and placing the concrete, it was decided to mobilize 10T & 13T cableways for the main block and Elba Cassor Tower Crane for portions, beyond the cableway range, pouring concrete in the overflow-bucket-portion.

4. COFFER DAM

For excavation job the river has be diverted through a tunnel. A cofferdam across the river has to be constructed between the upstream of the main dam and downstream of the diversion tunnel.

Diversion arrangements have to be made in advance of the construction activity.

For the coffer dam at Ranganadi the contractor had to pledge and quote tenders in a lump sum There already existed on its left bank a diversion tunnel of 6.8m dia, 254m long and 225 cumecs capacity.

The condition was that the contractor would submit its design in accordance with the submission made in the tender. The design would be approved by the clients and only then the coffer dam would be constructed. The contractor was to be held responsible for the safety and maintenance of coffer dams at his own cost throughout the construction period.

4.1 Tender Proposal for Cofferdams

The cofferdam upstream would be 22m high with a crest at EL 542 with a foundation of 13m and the downstream on would be 11m high with crest at EL 536.

4.2 Design Flood

The diversion arrangements have to withstand and handle floods during the construction. The design flood adopted for the cofferdam is 1800 cumecs albeit, the maximum observed flood was 1640 cumecs.

4.3 Actual Construction

The proposal was submitted for a colcrete coffer dam as shown in Fig.3. While excavating the foundations for upstream coffer dam, very large boulders mixed with riverbed material were found existing. It was time consuming and costly to remove them up to a depth of 12m before reaching the sound rock level. It was decided that the strata available after excavation for 2m was sound to bear the load of the coffer dam. While excavating care was taken not to disturb the underline material. The coffer dam design was cross checked against sliding, crushing at toe and tension at heel. Additionally, rock anchoring by 25mm dia bars at 2m c/c was provided. Hydraulic profile of the coffer dam was designed as envisaged to pass a flood discharge of 1800 cumecs.

Fig. 2 : Pictures of U/S coffer dam foundation colgrouting, under construction and completed view

The coffer dam was also checked for stability during the passage of flood.

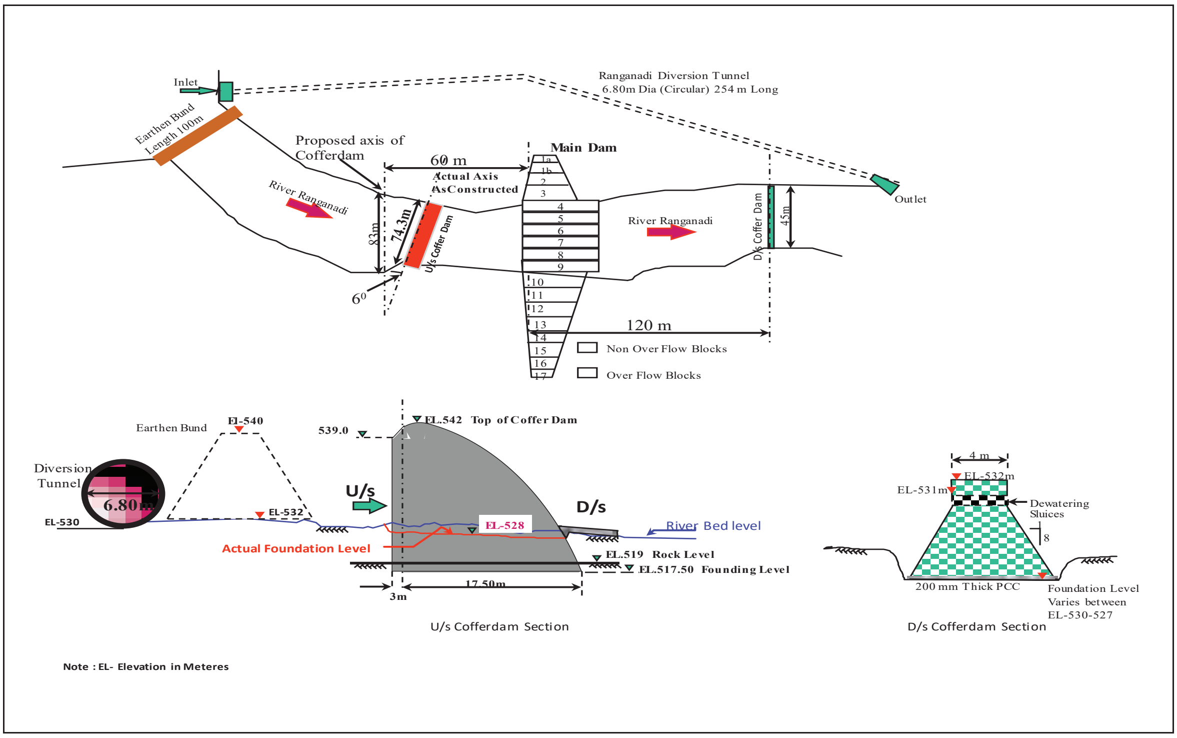

Fig. 3 : Proposal for colcrete coffer dam and sketch showing position and project details

4.4 Advantages of the innovation

The problem of seepage through the foundations, as the coffer dam was not founded on rock but on boulders, was tackled by providing extensive grouting (cement bentonite) near the upstream face of the coffer dam. The concept of design of dams on permeable foundations was adopted. It was ensured that beyond the toe of the dam, there was no exposure of material on which the dam was founded, by providing a concrete apron. This helped in limiting the exit gradient of the sub-surface flow to within safe limits to be contained within the safe limits and the measure also provided safety against the scour from water overflowing the coffer dam.

Adoption of the changed design helped us in completing the upstream cofferdam up to EL 538m over which the flood water passed through the due date. Despite the fact that the clients handed over the first quarry to us after 335 days, of commencement of work, the coffer dam was completed up to EL 542m, much ahead of schedule. Thus the cost of construction was economized and loss of a full working season was prevented.

4.5 Functioning

During the subsequent years, a close observation has been maintained on the scours in the downstream of the upstream coffer dam. Despite the passage of high floods (1152 cumecs) over the coffer dam there has been no scours on the downstream structures. The top of downstream coffer dam was used as road for transportation of material during the working season which reduced the distance between the two banks of river by 14 km approximately.

5. SELECTION PLANNING AND LAYOUT OF PLANT

Selection of equipment's is to be carried out for the main activities, i.e., (1) excavation (2) stone quarry (3) transportation (4) crushing of aggregates (5) collection and transportation of sand (6) cooling of concrete (7) mixing and batching of concrete (8) placement of concrete and (9) drilling and grouting.

Selection of equipments was made on the parameters of capacities, suitability and actual requirement and their compatibility with other plants in the link series. Because the ratio of progress in such projects depends on the interconnected functioning of equipments working in the series and any weaker link will hamper the same. Therefore the success mantra is "right capacity of equipment's at right location".

The next factor determining the capacity of a plant is the "time available for execution". This time factor is further sub-divided into two main stages-- time available for excavation and time available for concreting.

5.1 Excavation

Excavation of soft soil, river shingles, weathered rocks, hard rocks has to be done before acceptable foundation is reached. Excavation equipments have to be selected on the following parameters;

(i) Haul road construction required for hauling the material

(ii) Depth of excavation

(iii) Distance to the dumping yard, i.e., the lead

(iv) Approximate quantities under each class of soil.

Point (i) and (ii) will decide the number of the road making machines required.

Fig 4 : Dam Excavation using CK-170 and 1025 tippers

Point (iii) will determine the number of transport vehicles required per excavator. Number of excavators required is decided by calculating the excavation planned to be done per day v/s. the capacity of excavator to handle particular class of soil per hour/day. At Ranganadi Concrete Diversion Dam, the excavation required was 9.52,000 m^3 with the following breakup –

(a)	Soft soil	403218 m^3
(b)	Hard soil	337352 m^3
(c)	Riverbed material	49230 m^3
(d)	Weathered rock/disintegrated rock	145037 m^3
(e)	Hard rock	33179 m^3
	Total	**952000 m^3**

5.2 Quarrying of Stone and Transportation

Control and management of raw material is central to dam constructions. Completion of Ranganadi Dam concreting was planned with the peak pouring quantity of 22000 m^3 per month. The quarries at 3-4 location were identified and developed approximately at 4 km distance from the dam site, crushing-plant. Around 1000 m^3 of serviceable boulders were to be quarried and transported to 4 km distance every day.

To produce 1000 m3 of serviceable boulders, four 500 cfm compressors were installed. Drilling was done by jack hammers and wagon drills. The drilling activities were done mainly during the night hours. Primary and secondary blasts were made in daytime, at 5 a.m. and 12 noon. Serviceable stones of maximum 500 mm size were produced. The boulders were loaded in dumpers and transported to the crushing plant.

5.2.1 *Crushing of Aggregates*

Two numbers crushing plants of 150T/hour and 50T/hour capacity were installed to produce required quantity of aggregate. The sizes required were 150mm, 80mm, 40mm and 20mm down. Crushing was done with the help of –

5.2.2 *Crushing Plant – 1 (100T/hr)*

(i) Primary crusher –2 nos (Tele smith and Swedala make) – size 600 x 900mm

(ii) Secondary crusher – 2 nos (Marshall Marathon make Jaw Crusher) – size 600 x 450 mm

(iii) Tertiary Crushers :

Major Marshall – 2 nos

Roller Crusher – 2 nos

(iv) Apron Feeder – 2 nos

5.2.3 *Crushing Plant – 2 (50T/hr)*

i. Marshall Marathon Crusher – 1 no

ii. Marshall Magna – 2 nos

iii. Triple Deck Screen – 1 no

iv. Apron Feeder – 1 no

Crushing plants were operated for an average 14 to 16 hours per day and the remaining 8 hours were used for maintenance of the plants. Sequential operation of plant is drawn below.

Crushing Plant – 1

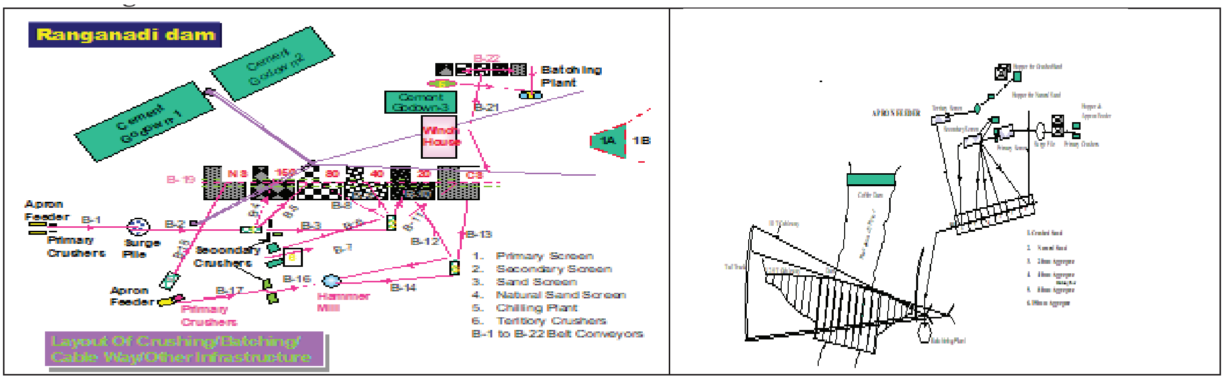

Fig. 5 : Sketch showing Crushing plant, batching plant, cement go down and cable way details

Serviceable boulders from the quarry were transported in dumpers and were unloaded onto two hoppers of approx. 30 m3 capacity each. Below the hoppers two numbers of Apron feeders were installed. These Apron feeders regulated the stone boulders to feed the primary crushers. The maximum boulder size fed to primary crusher was 500mm. The crushed material from the primary crusher was taken to stockpile by one 800mm wide conveyor belt. From the stockpile, the material was taken to one double-deck vibratory screen, from where 150mm aggregates were separated out and stocked in stock bins. Oversized and under sized boulders were passed to feed to the secondary crusher. The product of secondary crusher was taken to the triple deck vibratory screen by conveyor belt where 80mm, 40mm and 20mm down aggregate were separated and transported to the stock bins. The oversized once were fed into tertiary crusher and also taken to the triple deck screen, The stock bins were six in numbers and each bin had a capacity of 900 m3. Below the stock bins a reclamation tunnel was constructed with openings under each stock bin.

5.2.4 *Crushing Plant – 2 (350-400 mm size)*

Serviceable boulders from quarry were transported in dumpers and unloaded directly in hoppers of 30m^3 capacity each. Below the hopper, one Apron feeder was installed. With the help of Apron Feeder stone boulders were fed to the primary crusher. The crushed material from the primary crusher was taken to secondary crusher by gravity and then the crushed material transported to the triple deck vibratory screen through a conveyor system. The product was then stockpiled in 40mm, 20mm and 4.75 mm down stock bins. Below the stock bins a reclamation tunnel was constructed with openings under each stock bin.

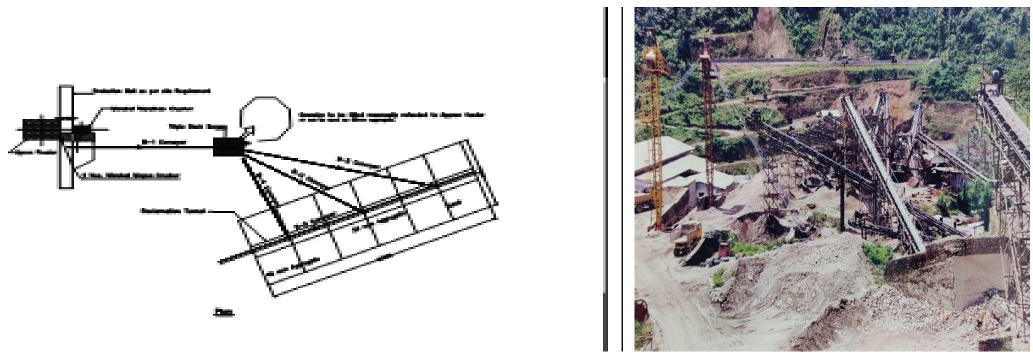

Fig. 6 : Crushing plant position and sketch showing reclamation tunnel for feeding batching plant

5.3 Collection and Transportation of Sand (Fine Aggregate)

A large quantity of sand is required for construction of a dam. Invariably natural sand is not available in required quantity. It is therefore necessary to go in for the crushed sand.

(i) For Ranganadi Dam both natural sand and crushed sand were used. Natural sand was collected from the riverbed from various sand collecting locations. The distance of these locations varied from 5km to 30km. Natural sand was collected from mid-stream river bed and shifted to the bank and loaded on to the dumpers. The loaded dumpers carried sand to the sand hopper where it was screened and then stored in sand bins with the help of conveyors.

(ii) For production of crushed sand for supplementing natural sand, one major Marshal Crusher was installed to crush boulders of 200mm to 40mm down. This was fed to a sand mill of BHS make. With this arrangement, it was possible to produce around $20m^3$/hr sand, i.e., approx. 320 m^3/day.

6. COOLING OF CONCRETE

At Ranganadi the atmospheric temperature rises as high as 40^oC during March to June. A placement temperature of 12^oC (later changed to 18^oC) was laid down in the contract. A chilling plant of 150 TR capacity was installed and chilled water used in the production of concrete in addition to ice flakes to maintain the placement temperature.

Precooling of concrete was done from March to June. The chilling plant was operated when the ambient temperature rose to 35^oC. Water was cooled to 40^oC and then used for the concrete. By the time the concrete was placed in the location, the temperature had gone down to 18^oC .

7. MIXING AND BATCHING OF CONCRETE

Various grades of concrete were required at different locations of the dam. The quantity of concrete involved was very large. It was therefore essential that a batching plant of a large capacity were installed to meet out the need of progress required per day per month. Batching plant had to handle a 150mm aggregate size. Different design mixes/grades of concrete were stored in memory of the batching plant control. These mixes could be recalled, batched and mixed as and when required depending upon the location of concrete pour. The location of batching plant was another important factor –

1. The Batching plant had to be located near the crushing plant to facilitate and to economise feeding aggregate.
2. It had to be located away from the dam excavation area.
3. It had to be as close as possible to the pickup point.

Considering these factors, a CIFA batching plant of 80m3/hour capacity was setup. The batching plant was having separate bins for different sizes of aggregates. A 200 ton of cement silo was provided for the storage of cement.

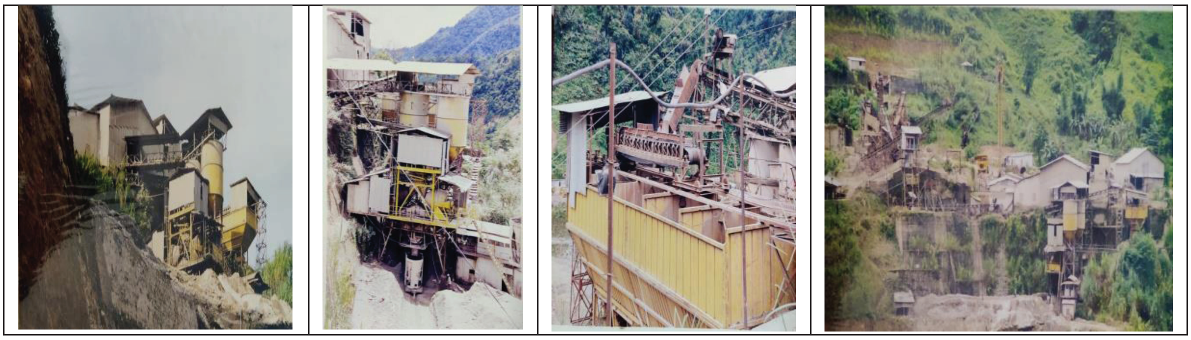

Fig. 7 : Picture showing Batching plant position and complete set up done skillfully at a very limited area

Weighing of aggregate, sand, cement was done by electronic load cells. The batching plant had 2nos mixers of 2m3 capacity, for unloading in to a common wet hopper. Dry weighed mix was fed to each mixer by a rotating chute. Measured ice flake and chilled water quantity based on designed w/c ratio was poured into the mixer. Aggregate of different sizes and sand from stock bins to the batching plant bins was transported by a conveyor through the reclamation tunnel; and through another conveyor to the batching plant. Various sizes of aggregates were transported by opening a particular size aggregate bin gate on to the conveyor through the reclamation tunnel. The aggregate is further shifted to the batching plant-bin, by yet another conveyor. Cement was pumped from the cement godown by the cement pump.

Concrete mix from the batching plant wet-hopper was unloaded into 4 m^3 capacity buckets stationed below the wet hopper on a trolley. Trolleys mounted on the narrow gauge rail track were operated through special winch arrangement between the batching plant and the pickup point

8. TRANSPORTATION AND PLACEMENT OF CONCRETE

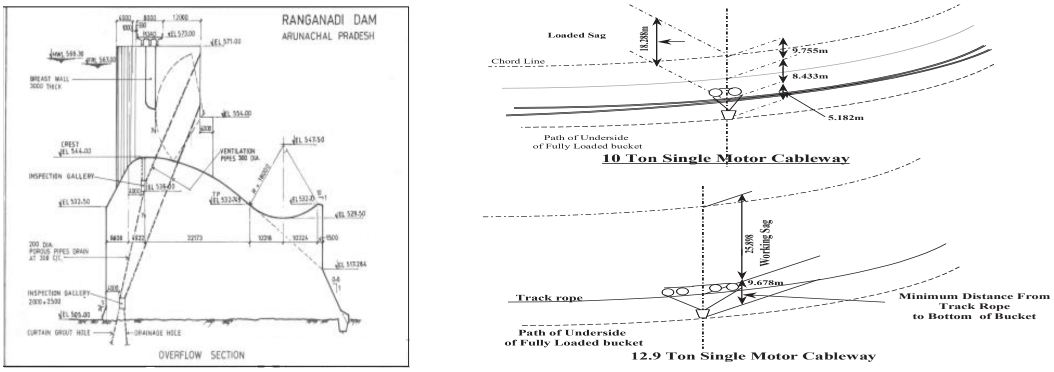

Fig. 8 : C-section of Ranganadi dam and tail car and sag position for transportation of concrete to dam blocks

One of the most important factors for progress of a dam is transportation and placement of concrete. To cover the entire large length and width of dam and to meet speedy placement of concrete on dams, a cableway is used. At Ranganadi Dam two cableways were set up, one of 10T capacity and another of 13T capacity. A Tail track of approx. 210 m length was constructed at EL 612. The same tail track was used for both 10T & 13T cableways. And still a portion of bucket of Spillway blocks 3, 4, 5 and 6 were out of the reach of the cableways. Therefore one Elba Casser Tower Crane was erected.

With the help of 10T and 13T cableways a maximum progress of 1224m^3 per day was achieved and maximum progress in a month went up to 22000m^3 with an average of 18000 m3/month.

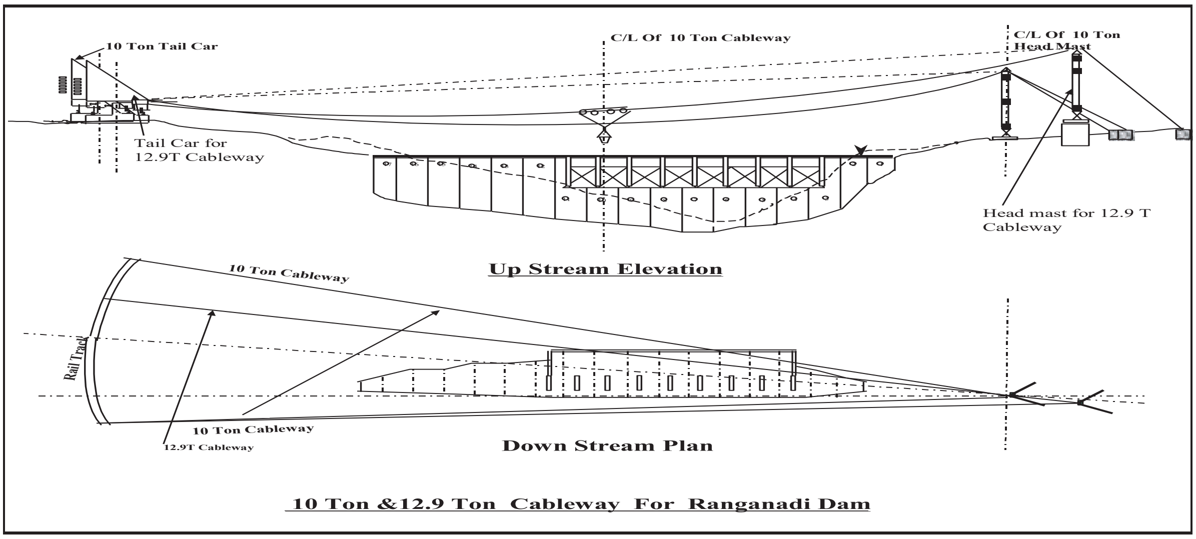

Fig. 9 : Crushing plant position and sketch showing reclamation tunnel for feeding batching plant

8.1 Shuttering

The Dams being the mass concrete works, the heat of hydration generated is very high; and therefore the lift of concrete placement is restricted. Cantilever type shutters are in common use for the upstream face, the downstream face and the side of the block. The upstream face has comparatively a mild slope compared to the downstream face. Same type of formwork can be used on the upstream, the downstream and the sides adjusting with the respective height and slope.

While designing the dam shutter, points to be taken into consideration are placement sequence, method of placement, rate of placement, concrete mix temperature and weather condition and cost.

Considering these points, a suitable mass concrete formwork was designed at Ranganadi Dam project site. Big sized shutter plates (1600m x 3000mm) were fabricated. These were handled by a hand-winch, mounted on a movable trolley. The measurements of the shuttering have been given in Fig.10.

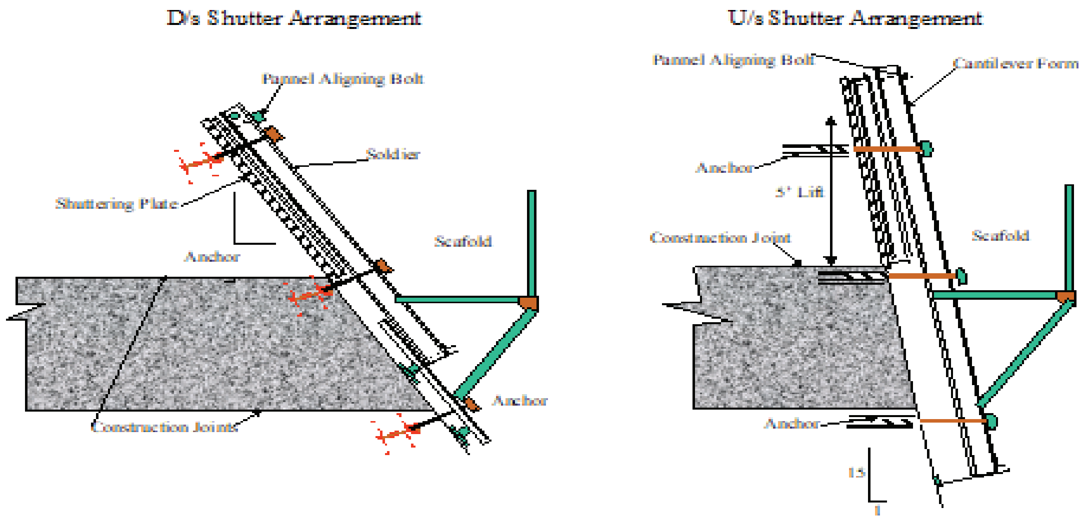

Fig. 10 : Up stream and down stream shutter arrangement for dam concreting

8.2 Vibration, Green Cutting and Curving of Concrete

Vibration and compaction of concrete (4m3 at a time) was done by using Dynapack make 150mm dia high frequency vibrators. Concrete was poured in three layers of 500mm each starting from the downstream side of dam.

Green cutting of the concrete was very efficiently done. The third layer of concrete was allowed to get completed to the minimum 1/3 width of the dam. Thereafter a cross bund of mortar was temporarily made (50mm high). While the concreting continued, on the other side green cutting of 4 hour-old concrete was done with the help of a 'Y' tube jet, i.e., a 10mm dia jet fixed to the tube connected to airline and waterline. Green cutting if done on time is so effective that no other treatment is further required for proper joint in between the block lifts of concrete.

Being a concrete mass, heat of hydration in the dam is very high and unless proper curing is done, cracks are likely to occur in the concrete. Sprinkling curing water on blocks faces problem as it is required to be shifted every time when the block concrete goes up lift by lift. At Ranganadi dam a water tank was constructed at higher elevation to ensure gravity water supply even if power failures occurred. Two pipelines were laid across the length of dam at higher elevation, one for water and another for air. This arrangement turned out to be foolproof.

8.3 Communication between cableways and batching plant operators

Though the control cabins of the cableway operators are provided with utmost care at locations from where the operators may see without hindrance the movement of the concrete bucket. To ensure delivery of the buckets to the exact locations the following two functions are monitored.

1. To monitor the height and distance of cableways in meters.
2. To monitor that walkie talkie sets are provided at block concrete locations, cableway operator cabin, batching plant operator cabin and the cabin of engineer incharge .From the block locations exact signals are given to the cableway operators to lower or hoist the buckets. For change of mix similar messages are communicated to the batching plant operators. This ensures the exact concrete grade at the exact location.

8.4 Drilling and Grouting

Drilling and grouting through the gallery for creating a high-pressure curtain was required. A very restricted gallery,1.5m width and 2.1 m height was available for drilling holes. It was not possible to use wagon drill or other heavy duty drilling equipments for drilling. Depth of curtain grouting holes was specified upto 50m maxim 8m and dia 50mm. Drainage holes of maximum 75mm dia and 40m depth maximum had to be drilled.

8.5 Finishing and Handling

After completion of all activities, it was proposed that a joint inspection of the site, each corner of the dam, with client engineers, would be done. Visual of the completed dam are given in Fig.10.

8.6 Quality Control

Special care was taken regarding quality aspects. Every norm was followed religiously. A well-equipped and sophisticated laboratory was installed at the site. Each batch of construction material was tested. Frequent inspections for consistent and homogenous quality concrete mix were done. Okay cards are being issued before every pour after inspecting and testing of (1) construction material; (2) shuttering alignments; (3) reinforcement fixing; (4) preparation

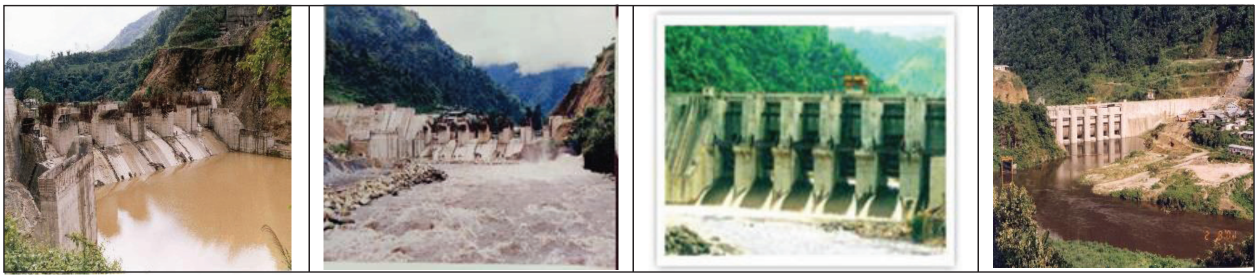

Fig. 11 : Dam view during construction and completed view pictures

of the surface over which concreting was to be laid (on some occasions, such as after the floods, etc. sand blasting was done to clean the surface); (5) preparation of joints between two adjacent blocks, etc. was properly monitored

9. HEALTH AND SAFETY IMPLEMENTATION

To ensure safety of people working at this mega project, we had established a health and safety department at the site with a team of safety experts and a medical staff. Regular awareness programmes regarding work safety, importance of PPE's, project activities information, hazards and mitigation measures of hazards, safe working procedures of every activity, basic safety rules, fire protection system, accident prevention and control, emergency systems and preparedness, motivational training and safety movie presentation had been conducted on a regular basis for the engineers, workers and laborers. The safety department had conducted a routine induction programme for the visitors coming to the site before they entered, into the project area.

Usually dam operations are quite hazardous and the chances of minor and major accidents are high. Maximum precautions were taken during the construction of the dam excavation, reinforcement works, cableway and tower crane operations and block concreting.

During the construction stage, one well equipped first-aid post with the following facilities: qualified doctor, male nurses, first aid box with essential medicines including ORS packets, first aid appliances-splints, dressing materials, stretcher, wheel chair, ambulance, van etc, was provided at the site to meet any emergency. Also a liaison, was kept with the district hospital at North Lakhimpur and the nearest PGI for treatment of our people in case of emergency.

10. CONCLUSION

The challenges accepted during the construction of the project were working at remotest location of a remotest state where communication local and national was the first priority for this purpose a comprehensive V sat communication was established. The sets were used not only for telephonic communications but also for e communications like fax and email. Wireless sets were used for internal communications and ever ready vehicle for road communications. A dedicated team of engineers and workers was put together which was committed to working day and night and succeeded in completing the work on time. The management of material needed and supplied was put in order so that the work could not stop even for an hour. The latest technical know-how was used to maximize the construction speed and minimized the cost. Every department of construction worked in coordination with other departments and also took care of its own work. One of the secrets of the success was high priority maintenance of key plants like the crushing plants, batching plants and cableway plant. And hovering like grace over the entire project world was the tender care employees welfare. Treating each employee like a member of the project family, they were provided with medical care, bonus, insurance and any eventuality rising in their families. The following is the crux of experiences and experiments done and derived through this project.

- Proper planning and accurate layout.
- Simultaneous execution of jobs.
- Availability of raw material.
- Timely construction of waterways over the coffer dam.
- A scientific human resource management and their safety from work hazards.