https://doi.org/10.36375/prepare_u.iei.a112

Adoption of Modern Technology in Irrigation Projects- A Case Study of Ongoing Polavaram Project in Andhra Pradesh

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Abstract

Andhra Pradesh state has taken up Polavaram Irrigation Project across Godavari River with a gross storage capacity of 195TMC (utilization-322TMC) which is presently in progress. The main dam components are- Spillway and the main Earth Cum Rock Fill Dam (ECRFD) of 1.75km length and to a height of 48 Mts. The major Challenge is to build ECRF Dam over deep permeable sand bed of about 60-90M. Since conventional Cut off for such dams is problematic, Plastic Concrete Diaphragm cut off wall utilizing modern international technology and machinery was now resorted to by Project. Another challenge that was faced in the project is "building upstream and downstream coffer dams" that has to facilitate construction main ECRF Dam on Godavari River which usually experience flashy floods. In order to overcome permeable sandy foundation strata for the Cofferdams, in place of conventional Z-type Sheet pile cut off of 20M -30M, an alternate foundation soil stabilization technique by ***Get-Grouting****, an international technology was adopted for cofferdams' foundation to facilitate the construction of main ECRF Dam for early completion of project to accrue its intended benefits.*

GET-GROUTING soil stabilization: *The construction of cofferdam on granular soils involves geo-technical problems of water seepage and potential piping below temporary cofferdams. As per requirement of coffer dam design, Z-Sheet pile steel cut off with 18-20mm thick metal specification for 29M depth for upstream Coffer dam (2.3km length) and 16M depth for downstream Cofferdam of (1.57km length) are needed. There was a problem of availability of 18-20mm thick Z-type Sheet Piles, otherwise to import of which likely will cause delay in the project in construction. An alternate Get- Grouting Soil stabilization for cofferdams was proposed being the modern technology. In order to control the seepage below coffer dams, Jet Grouting technique has been chosen based on overall exit gradient and duly conducting seepage analysis.*

PASTIC CONCRETE DIAPHRAGM Cut off Wall for Earth Cum Rock Fill Dam: *A Diaphragm wall is a civil engineering technique used to build reinforced concrete walls in areas of soft earth or sand close to open water, or with a high groundwater table. This technique is typically used to build diaphragm (water-blocking) walls in open cuts, to lay foundations and arrest seepage through foundation. This modern technology was adopted for execution of main Earth Cum Rock Fill Dam of 48M height and 1.75 km long across Godavari River having deeper sandy bed needing 60-90 mts deep as Cut off Wall (COW) with embedment in to impervious strata to overcome the technology challenge in the project. For smaller depth of impervious strata, conventional cut off trench beneath Earth dam is a general practice. But in the present case an order of 90 Mts cut of is to be done where seepage permeability is an about 3-6 cum per day per meter width. In order to overcome this technical problem, Plastic Concrete Diaphragm wall technology with deployment of imported machinery was resorted to.*

The Polavaram ongoing Irrigation project across Godavari River in Andhra Pradesh has been the conceived over 8 decades back and delayed due to Geo-Technical Engineering Problems. Eminent international experts viz. Dr Karl Terzaghi, Professor of Soil Mechanics; Dr JL Savage Chief Engineer from USA and Sir Murdole Macdonald, a famous Consulting Engineer (ASWAN Dam) of London have either visited site or imparted technical advice on foundation problems of the project. Finally the project is becoming a reality with adoption modern technology of this century by overcoming foundation problems with adoption of ***JET-Grouting*** *soil stabilization for coffer dam foundations and* ***Plastic Concrete Diaphragm C****ut Off Wall (COT) beneath Earth Cum Rock Fill (ECRF) Dam during 2019.This Multipurpose Dam is becoming a reality and making it possible by adoption of Modern Technology in civil engineering construction to benefit seven (7) lakh hectares new command and Hydro-Power generation of 960 MW to enhance GDP of not only the State but also the Nation.*

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https://doi.org/10.36375/prepare_u.iei.a112

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1.0 Preamble:

Water is one of the five life sustaining elements called ‘Panchbhutas’ and is a renewable Natural resource that can be exploited for benefit of mankind and society at large. Water is called ‘Jivanam’ in Sanskrit means the way of life and is a priceless gift given by nature for sustenance of all kinds of life in the universe. Water plays an important role for Drinking water, Agriculture, Production of essential commodities, Hydro Power generation, Industrial production, Recreation, Transport, and Environment. Water is responsible for Global civilization and culture which ultimately led to present economic growth and enhanced living standards of people. Hydrosphere is the combined mass of water found below and over the surface of planet Earth. On earth there is 1386 million cubic kilometers of water which includes liquid and frozen forms of ground water; oceans; lakes; and streams. Salt water accounts for 97.5% of total water and rest 2.5% is fresh water. Even in this total fresh water, about 68.7% is locked up in Glaciers and 29.9% exists as fresh ground water ultimately making only 0.26% of total amount of fresh water on planet earth. It is easily accessible as surface water in the reservoirs, lakes, water bodies and river systems.

2.0 Water Resources in India:

India has 16% of the world's population, 4% of the world's water and only 2% of land area. The country receives about 4000 km^3 of precipitation in a year. However, as much as 3000 km^3 of this comes as a rainfall in a short monsoon period of 3 to 4 months from June to September. Even this availability of water is not uniform and is highly uneven in both space and time. Average annual water resource potential of the country is estimated as 1869 cubic km. Considering the constraints of hydrology, topography and geological limitations, only 690 cubic km. of surface water can be utilised by conventional storage and diversion structures for optimal use of water. Turning to (dynamic) groundwater, the quantity that can be extracted annually has been estimated to 432 km^3.The systematic water resources development works have been carried out through successive Five-Year Plans that followed since 1950. Presently the mechanism of financial resources mobilization for irrigation development is looked after by Niti - Ayog of Government of India.

The National Commission on Water has made various assumptions in regard to these matters (high, medium and low rates of change), and came to the conclusion that by the year 2050, the total water requirement of the country will be 973 km^3 to 1180 km^3 under `low’ and `high’ demand projections, which means that supply will barely match demand. It is the Commission’s view that there will be a difficult situation but no crisis, *provided* that a number of measures on both the demand side and the supply side are effectively taken on time.

The concept of `water stress’ may not be out of place in this context. Dr.Malin Falkenmark, the leading Swedish expert, has calculated the `water stress’ situation of different countries with reference to `Annual Water Resources per capita’ (AWR). An AWR of 1700 m^3 means that only occasional and local stress may be experienced; an AWR of less than 1000 m^3 indicates a condition of stress; and one of 500m^3 or less means a serious constraint and a threat to life. But the present situation in India will

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be adversely change with the growing population by 2050. India is likely to join the ranks of `water-stressed' countries in the future if counter measures are not taken up in right earnest.

The Indian rivers are carrying water of an order of 1953 billion cum with country's average rainfall of 1170mm which is accounting for 400milion Ha.Mts.in volume. The utilizable water resource is order of 1086 billion Cubic Metres (BCM) against which present utilization is of the order of 600 BCM and the reason being for want of additional Storage Dams. The present storage capacity of all reservoirs in India accounts for only 175 BCM or 6180 thousand Million Cubic Feet (TMC) requiring to build more dams to accommodate total storage of 400BCM or 14126 TMC for future needs of the country.

3.0 Ongoing Polavaram Irrigation Project in Andhra Pradesh:

In the endeavour to build large storage Dam, the State of Andhra Pradesh has taken up Polavaram Irrigation Project across Godavari River on upstream of Sir Arthur Cotton Barrage (Dowlaiswaram Barrage) near Polavaram (v) in West Godavari District with another flank in East Godavari District. The gross storage capacity of Polavaram project is 195TMC (utilization-322TMC) and this is an ongoing project. The project is intended to benefit 2.95 lakh Ha. (7.2 lakh acres) of new ayacut, stabilization of 4.00 lakh Ha. of stabilization and drinking water supply to 540 villages with a population of 28.5 lakhs. This dam also generates Hydro Power of 960MW.

3.1 Salient Features of Polavaram Project:

Table-1

Polavaram Project: Salient Features

1.	FRL	+45.72M (+150ft)
2.	MDDL	+41.15M(+135 ft)
3.	Spillway crest	+25.72 M(+84.39ft)
4.	Length of Spillway	+1128.40M(including NOF)
5.	No Of Radial Gates	48 Nos of 16 M X 20M
6.	Earth Cum Rockfill Dam:	
	a. Height	48.00M
	b. Length	2454.00M
7.	Gross Storage	:194.6 TMC (5.510 TM Cum)
8.	Live Storage	:75.20 TMC (2.219 TM Cum)
9.	Utilization	:273.0 TMC (7.730 TM Cum)

Polavaram Project: Salient Features

10.	Design Flood	:36.00 Lakh Cusecs (1.02 lakh Cumecs)
11.	Probable max Flood	:50.00 Lakh Cusecs (1.40 lakh Cumecs)
12.	Right Main Canal	:174.00KM (1.29 Lakh Ha)
13.	Left Main Canal	:181.00KM (1.62 Lakh Ha)
14.	Hydro Power	:960 MW (12 X 80 MW)
15.	Inter Basin Transfer to Krishna	:80 TMC (AP Share-45TMC)
16.	Water Suplly to Vishakaptnam :	23.44 TMC
17.	Drinking water :	28.5 Lakh Population (540 Villag
18.	Stabilisation of Godavari Delta:	10.13 Lakh Acres
19.	Source to Indira Sagar LIS :	1.33 Lakh Acres

4.0 Adoption of Modern technology in Polavaram Project:

The major head work components of Polavaram project are- Spillway of 1.128km length to pass a flood discharge of 50lakh cusecs, main Earth Cum Rock Fill Dam (ECRFD) in the river portion is of 1.75km length with a height of 48 Mts and 960 MW generation capacity Hydro Power House. The major technical challenge is to build ECRF Dam over deep permeable sand bed of about 60-90 M deep. Since conventional Cut off underneath of dam foundation such as Sheet pile driving to such greater depth for such dams is problematic, a Plastic Concrete Diaphragm Cut Off Wall (COW) utilizing modern international technology and machinery has been adopted.

Another technical challenge that was faced in the project is “Building upstream and downstream Coffer dams” that has to facilitate construction of main ECRF Dam in one working season is very critical on Godavari River which usually experience flashy floods. In order to overcome the permeable sandy foundation strata for the Cofferdams, conventional Z-type Sheet pile cut off of 20M -30M deep have been originally proposed in the design. This process is very much time taking to procure required Z-Sheet Pile material of that specification of 18-20mm thick requiring import by placing a special indent, which the project cannot afford such for its early completion. Hence an alternate foundation soil stabilization technique for Coffer Dams by JET-GROUTING soil stabilization, an international technology was adopted for the cofferdams foundations for further taking up main ECRF Dam having a length of 1.75km length across main River.

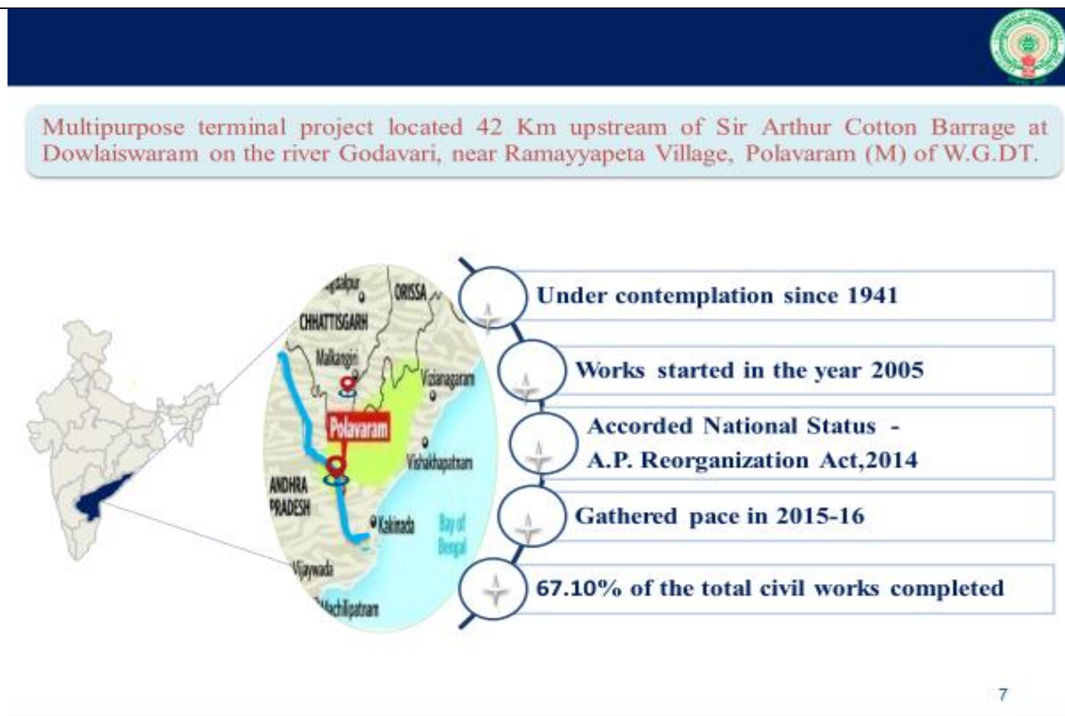

Fig: 1-Index Map of Polavaram Project:

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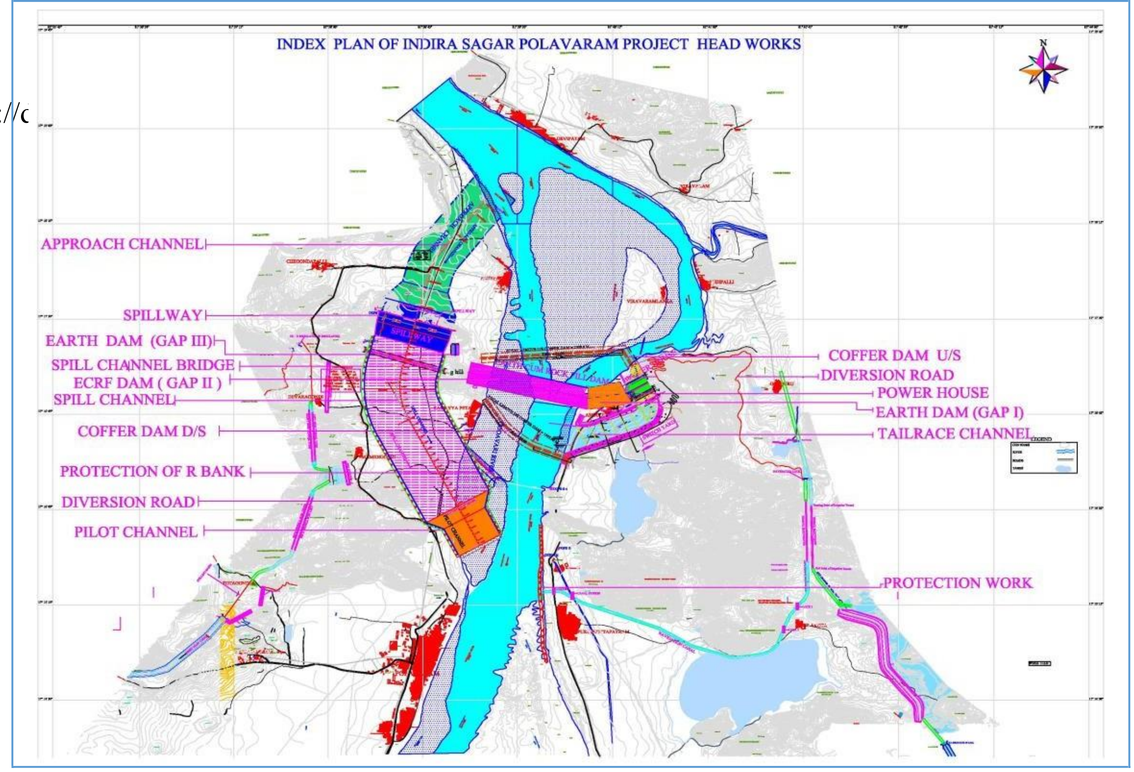
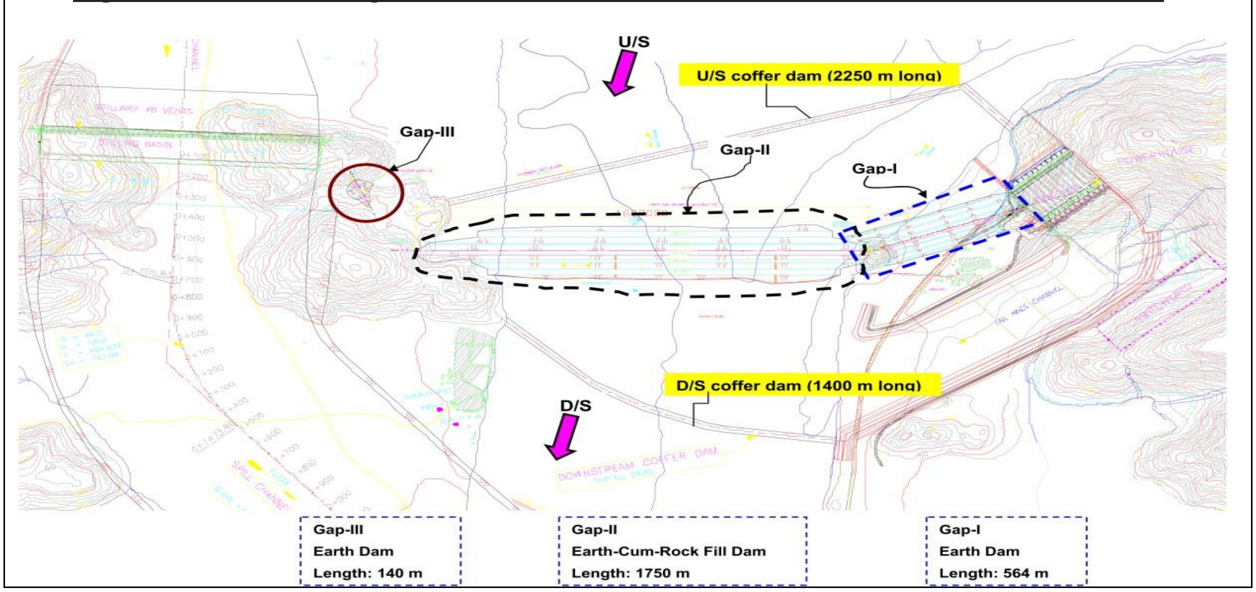


Fig:2 Location Map & History of Polavaram Project:

5.0 JET-GROUTING Soil Stabilization to overcome permeable foundation (Sandy Strata) for Cofferdams:

Fig: 3-Site Plan Showing Location of Coffer dams and Main Earth Cum Rock Fill Dam



Jet Grouting is a process consisting of disaggregation of soil and mixing it with a cementing agent or binder. This is achieved by high energy jets of grout comprising of a water/binder suspension injected through a nozzle, by which the soil around the borehole is eroded. The eroded soil is brought into suspension, the soil particles rearranged and mixed with the cement suspension, which subsequently sets and hardens to form a stabilized column of jet grout. Different geometrical configurations of jet

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grout columns can be produced based on the project requirement with a minimum diameter of 130mm extending 200mm to suit site conditions. The primary requirement of the jet grouting in this instance is to reduce the permeability of the granular soil in the cut-off wall to less than 1 x 10^{-6} m/sec beneath the cofferdams which facilitate to construct main Earth Cum Rock Fill (ECRF) Dam on the run of the river.

The construction of cofferdams on granular soils involves geotechnical problems of heavy water seepage & potential piping below temporary cofferdams. The typical width & height of cofferdam at Upstream is about 173m & 31.5m and that of downstream is of order of 118m & 20.5m at Downstream. As per requirement of coffer dam design, Z-Sheet pile cut off with 18-20mm thick metal specification for 29M depth for upstream Coffer dam (2.3km length) and 16M depth for downstream Cofferdam (1.57km length) are needed. But the major Indian steel manufacturer, M/s SAIL is manufacturing only 10mm thick Z-type Sheet Piles and alternate importing of required design specification sheet pile of 18-20mm thick will be very much time consuming there by cause delay of project completion by more than a year or two.

Hence the project authorities have finally decided to go in for **Jet- Grouting** Soil stabilization for cofferdams which is the modern technology with imported machinery. To control the seepage, Jet Grouting technique has been chosen based on overall exit gradient and duly conducting seepage analysis.

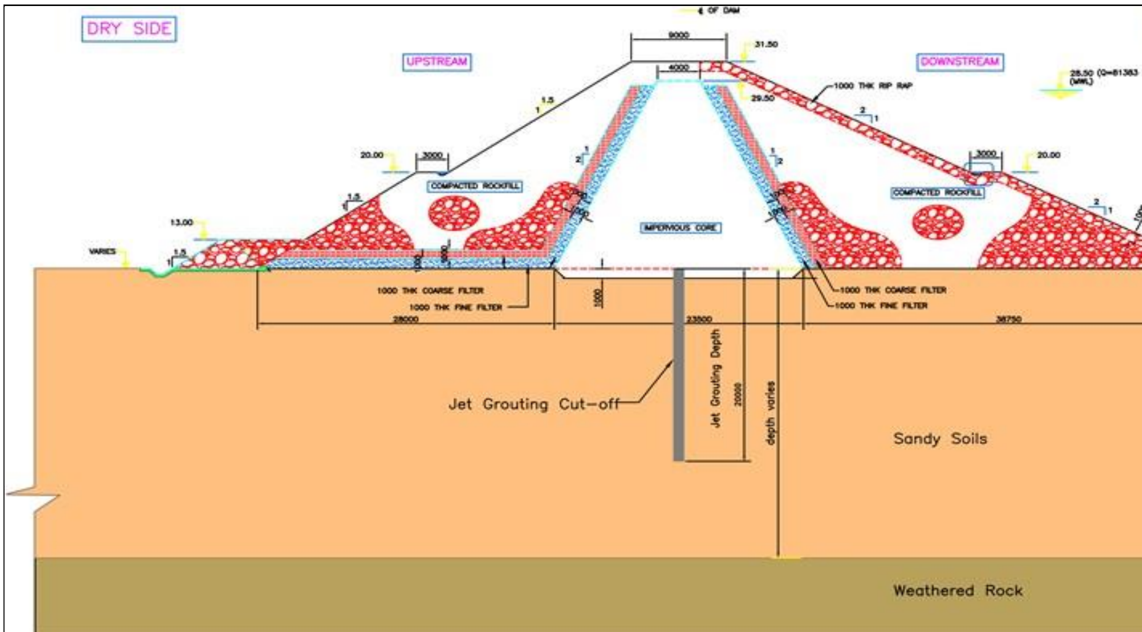
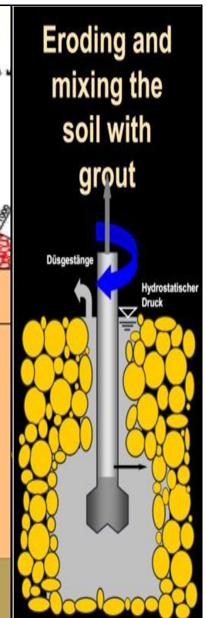


Fig: 4-<u>COFFER DAM SECTION</u>



<u>Fig:5-Basic Concept of Jet grouting</u>

5.1 JET GROUTING PROCESS:

Jet grouting comprises of two prime processes, being the drilling & grouting process. The proposed jet grout cut-off curtain comprises of a single row of over-lapping large diameter jet grout columns, spaced to ensure that the grout column body formations will overlap with each other to form a continuous cut-off barrier.

Drilling is performed by rotary drilling methods, using a water or grout flush to form a hole in the order of 130 to 200mm in diameter. This assists with the return of jetting spoil during the jetting operations.

Jetting is carried out from the “bottom up” through controlled extraction of the drill rods which are fitted with specialized Double Fluid (D) Jetting equipment. The two fluids being employed include: **water/binder grout suspension and air**. The fluids are injected through a two-fluid monitor and nozzle. The water/binder grout suspension is injected through the center of the nozzle under high pressure while air is introduced as a shroud around the high-pressure grout to aid the penetration and mixing efficiency of the grout with the sands. The air also facilitates the release of the spoil return to the surface.

The jetting is carried out as a “bottom-up” operation in which the drill string, with the jetting monitor attached at the base, is slowly raised and rotated while injecting the grout to form a column of soil/cement. During jetting, the spoil returns (excess material from the soil/grout mix) rise to the top of the drill hole, aided by the air from the air shroud, from where they are diverted from the jetting position site.

The jet grout column characteristics (diameter, composition, permeability, strength of the columns, effective thickness of the cut-off wall etc.) are dependent on the jetting parameters employed. These include rotation and extraction speeds, jetting pressure and grout flow rate, the grout mix, as well as soil type, grain size distribution and consistency of the in-situ soils.

The jetting parameters are dependent on the prevailing site conditions and as such are determined and verified on site during the initial stages of the project. Jetting parameters and grout mixes will be reviewed and may be refined throughout the production phase based on site observations and the outcome of test and Quality Assurance (QA)/Quality Control (QC) data.

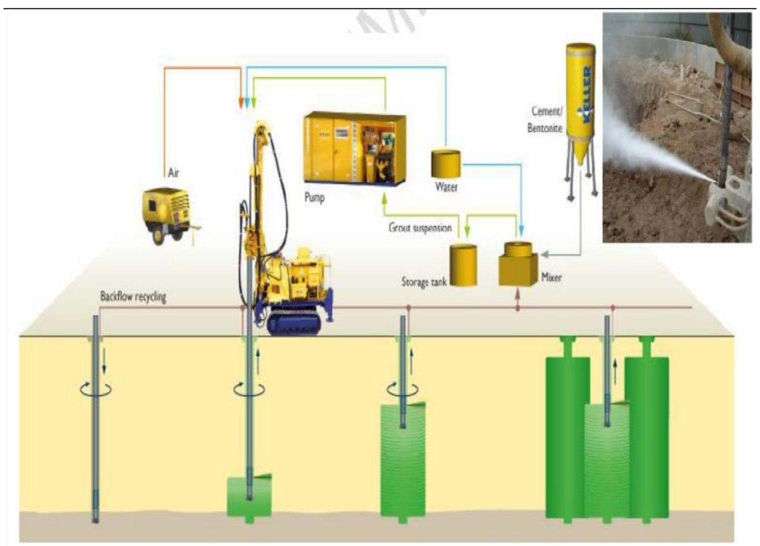


Fig:6- Jet Grouting Installation and Nozzle Flowing

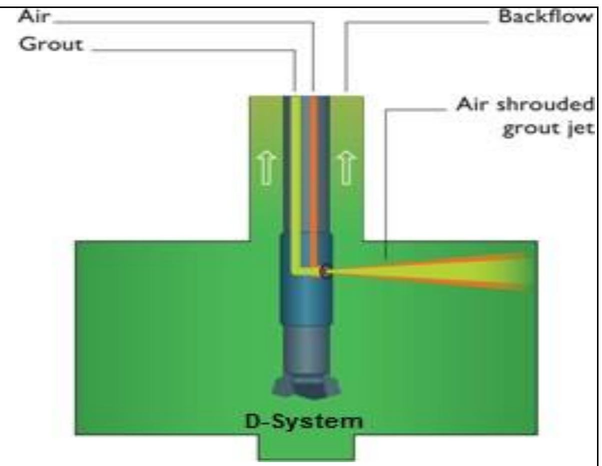


Fig:7- Method of Jet Grouting Process

5.1.1 Grouting operation will be carried out by installing successive grout columns using a “Fresh in

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Fresh" sequence working continuously in one direction where possible. This will ensure maximum erosion of the recently installed grout column and building the new column thereby optimizing the interlocking and overlapping of the columns. The drilling/grouting equipment will be marched in a direction working away from the completed columns and spoils returns. However, alternative columns installation may be adopted in specific ground conditions where there is no possibility of employing a successive method of installation of columns, termed as" Fresh in Fresh" installation.

5.1.2 Grout Mix Materials: The grout slurry will consist of a homogeneous mixture of Portland Pozzolana Cement (PPC), and Water, with the possible addition of bentonite and/or other additives. It is noted that this proposal is based on the assumption that the on-site water source (river flow) is free of deleterious materials and suitable for jet grouting purposes. The water will be tested to ensure this assumption is correct and has no adverse effect on the setting or hardening the jet grout mix.

5.1.3 Mixing of binder: The powdered binder (comprising cement and possibly pulverized fly ash / PPC, bentonite or other additives) and water will be mixed in recirculated colloidal or jet valve grout mixers. With both of these systems, the powder is introduced into a high-pressure stream of water and the components mixed into a cementitious grout suspension. The cement flow and water flow can both be adjusted to generate the grout consistency and quantity desired. The mix proportions will be measured by specific gravity of the grout which will be measured and monitored through a mass flow meter and checked by mud balance.

5.1.4 Jet Grout Column: The diameter of the formed jet grout column will be checked during initial stage of works by excavating the treatment area up to 2-3m. The exposed columns will be visually inspected and the diameters and overlap measured and checked to ensure that the operational parameters have achieved the design dimensions. The column identification shall be verified once the drill rig is set up on the design location.

5.2 DRILLING AND GROUTING PROCESS:

1. The Jet Grout Column identification shall be verified once the drill is set up on the design location.
2. The inclination of the mast will be checked for verticality to ensure the hole is drilled in a vertical alignment.
3. The depth encoder will be reset to zero based on the location of grout nozzle monitor location relative to the working platform level (not with the tip of the drill bit depth).
4. Drilling will be carried out up to the specified design depth (base of cut-off wall level) relative to the starting level
5. The depth of drilling will be monitored and recorded continuously in the Data Acquisition (DAQ)system.
6. Grout pressure at design flow will be initiated once drilling is completed with the design flow and pressure regulated and monitored throughout the grouting process.
7. The jet grout monitor will be withdrawn at specified withdrawal rate while maintaining the constant rotation speed (rpm).
8. After completing the treatment at the cut-off level, grout flow will be stopped to allow pressure to dissipate.

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9. DAQ recording of the column installation will be stopped and the monitor removed from the column location.
10. The project engineer will review jet grout column DAQ reports to ensure that the columns are installed in accordance with the submitted and verified parameters.
11. The Engineer may revise and refine the production parameter throughout the works as confirming quality results are achieved.

    However, all these operating parameters will be defined after installation of initial columns to suit site specific conditions before commencement of the main works.

Table-2. Proposed Operational Parameters for Jet Grouting

S. No.	Description	Parameter Range
1	Grout Flow	250 to 450 Its/minute
2	Grout Pressure	300 to 450 bars
3	Withdrawal Rate	10 to 30 cm/minute
4	Rotation per minute	4 to 12 RPM

5.4 Grouting Process starts upon completion of a jet grout column, the column location shall be topped up with jet grout spoils to ensure the required design cut-off level is maintained. Spoil Handling is an important operation in Jet Grouting since large amount of spoil returns are generated during the jetting of the columns. The composition of the spoil is a mixture of the grout and the in-situ soil and has an initial fluid/ paste consistency which sets after a period of 24 to 72 hours.

The volume of spoil returns is expected to be of the order of 30-50m^3 for a 20m long 2m diameter column. The spoil returns will be diverted away from the jetting operations to an area close to the working platform from where they will need to be removed and disposed of by others on a regular daily basis.

5.5 Quality Control Tests: During production of Jet Grout columns, the spoil return will be usually observed with regard to volume, appearance, flowability and consistency. Any variation will be recorded on the Jet logs and brought to notice of Project Engineer in Charge.

5.6 Wet Grab Soil Cement return samples will be collected from "Spoil Return" for testing duly collected from jetting of Upper, Middle and Lower sections of selected columns. The Cylinder of size 50mm **x**120mm test samples after curing have to be tested for permeability in QC Laboratory of appropriate standards.

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6.0 CONCRETE DIAPHRAGM Cut off Wall for Main Earth Cum Rock Fill (ECRF) Dam:

A Diaphragm wall is a civil engineering technique used to build reinforced concrete walls in areas of soft earth or sand close to open water, or with a high groundwater table. This technique is typically used to build diaphragm (water-blocking) walls in open cuts, to lay foundations and arrest seepage through foundation of dams. The Construction of main Earth Cum Rockfill dam of 48M height and 1.75 km long across Godavari River with deeper sandy bed needing 60-90 mts deep cut off wall with embedment in to impervious strata is another Technology challenge in the project. For smaller depth of impervious strata, conventional cut off trench beneath Earth Dam is a general practice. But in the present case,60- 90 Mts cut of is to be done where seepage permeability is an order of 3-6 cum per day per meter width. In order to overcome this technical problem, Plastic Concrete Diaphragm wall of deeper depth technology with deployment of imported machinery was resorted to.

Fig:8-Machinery of Diaphragm Wall and Placement at Dam Site

Materials for Diaphragm Wall: Cement, Bentonite and admixtures, Crushed aggregates (max. size 12.5 mm) and river sand (0 to 4.75 mm).

Bentonite: The proportions of the slurry supporting fluid shall be altered to meet construction conditions by adding appropriate admixtures at the discretion of Project for the proper consistency of the slurry and for the stability of the trench excavation. The Bentonite used to produce the slurry shall be in accordance with the latest edition of the American Petroleum Institute Standard 13A or any other known and appropriate standard.

Testing of Bentonite Slurry: For any 1 ton of bentonite used, it shall be tested and shall not deviate by more than 2% for moisture content; □2cP for the apparent viscosity and a gel strength at 10 minutes after batching of 2 N/m² measured by ball harp method as per DIN EN 4126.

Admixtures for Bentonite Slurry:

- Sodium-Bi-carbonate in case of cement contamination
- CMC / PHPA types for adjusting viscosity, filtrate loss
- Polyacrylate for plasticizing, de-sanding improvement

Table -3

STATEMENT SHOWING THE PROPOSED BOTTOM LEVELS OF DIAPHRAGM WALL

S. No	Chainage (in M)	ngth in m	Ground level/River bed level (M)	esh rock level	2 m anchoring in fresh rock	Total Depth in m
1	0					
2	30					
3	150	120	8.40	-29.72	-31.72	40.12
4	270	120	6.78	-29.73	-31.73	38.51
5	390	120	12.46	-42.90	-44.90	57.36
6	500	110	15.61	-82.39	-84.39	100.00
7	540	40	15.09	-56.83	-58.83	73.92
8	640	100	13.52	-29.43	-31.43	44.95
9	750	110	14.39	-25.31	-27.31	41.70
10	915	165	15.25	-31.15	-33.15	48.40
11	1050	135	16.16	-15.34	-17.34	33.50
12	1200	150	16.09	-13.97	-15.97	32.06
13	1350	150	17.36	-15.79	-17.79	35.15
14	1445	95	26.32	-2.44	-4.44	30.76
15	1730	285	53.99			
16	1750	20				

6.1 The Cut of Wall (COW) consists of approx. 68,112 m² of area with a length of approx. 1,440 m (from Chainage CH-58.80 m to CH-1550 m). The average depth from working platform level is approx. 47 m including 2 m rock socketing whereas the maximum depth to 110 m from working platform level is considered at approx. CH-500 in Stage-2 area. One special hydro-cutter for a max depth of 150 m is considered for the project. The thickness of the wall is specified with nominal 1500 mm. **COW** embedded two (2) meter into alluvium/rock contact surface and concreted up to the top of the guide wall. The effective cut-off wall will end at the bottom of the guide wall, allowing to prepare and install the head of the COW / Diaphragm. For the Cut-off wall alignment, the nominal COW-thickness of d_{COW} = 1.50 m may be reduced at depth due to the system intrinsic verticality deviations of up to 0.3%. The overall system permeability is not jeopardized with possible verticality deviation of the individual panel.

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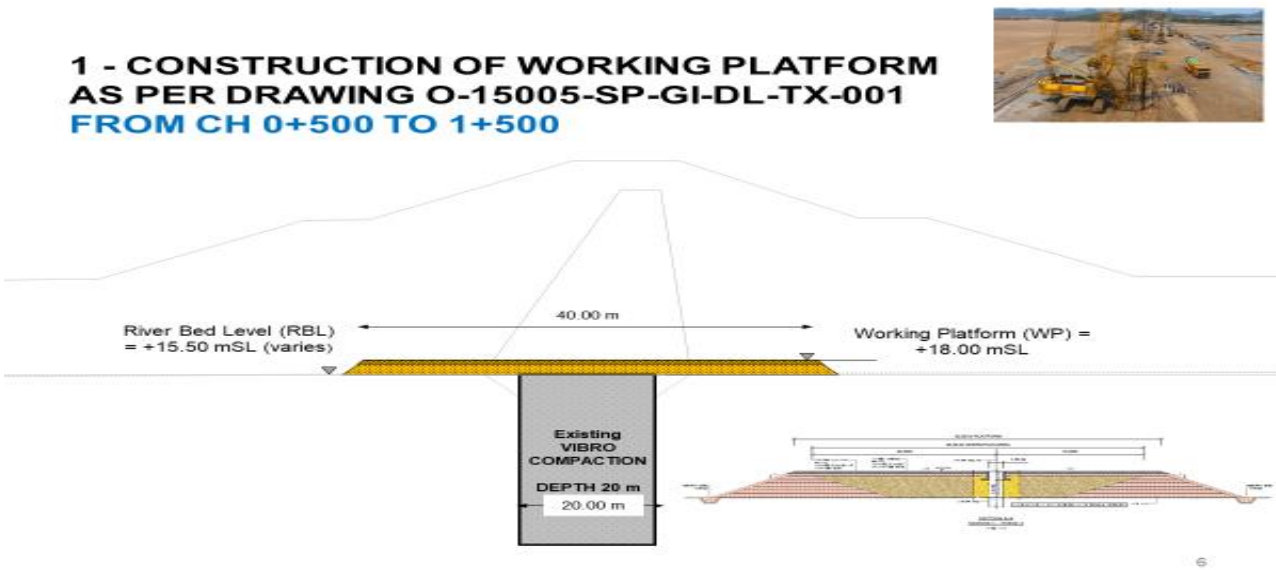

Fig: 9 – Construction Arrangement for Diaphragm Wall:

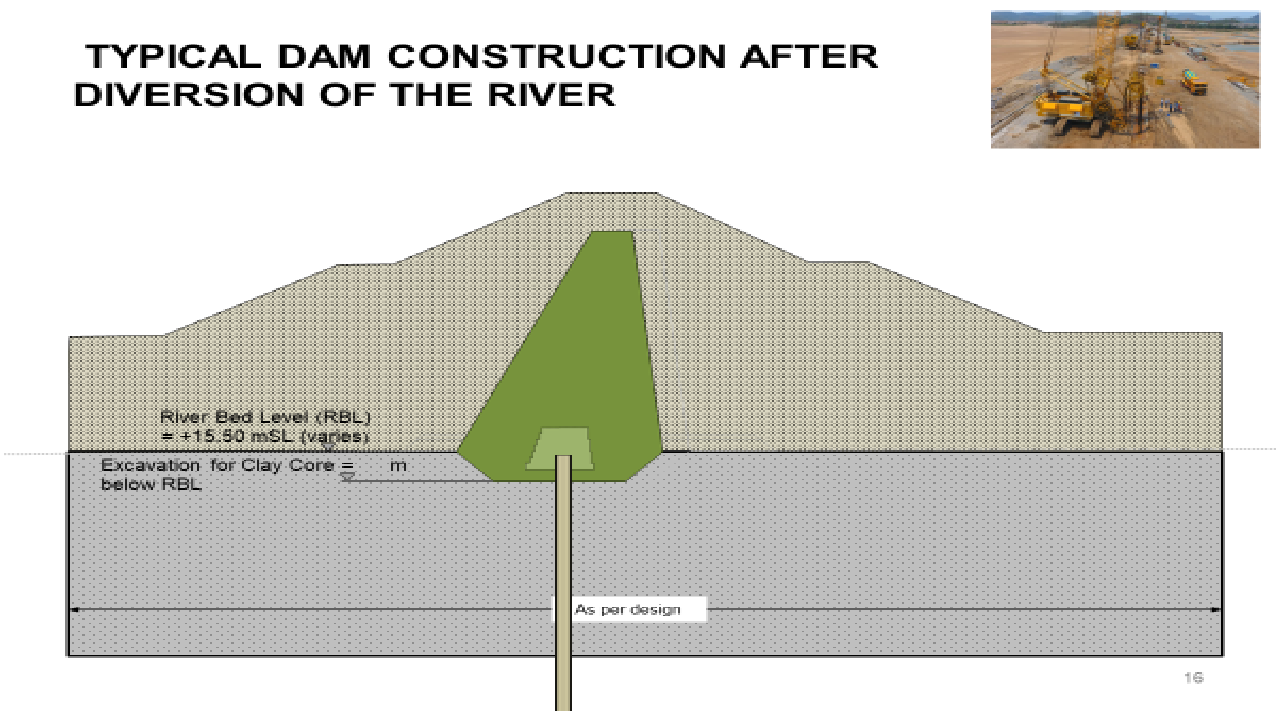

Fig.10 Typical Earth Cum Rock Fill Dam Section:

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6.2 PLASTIC CONCRETE:

For good workability and flowability of the COW concrete, the proposed concrete properties are based on the experience of more than 20 years of designing and installing plastic concrete in diaphragm walls forming concrete cut-off walls. Deviating from these properties could jeopardize the quality of the COW for the project.

Properties of Concrete requirements for samples at the age of 28 days:

– Unconfined compressive strength	≥ 1.0 MPa*
– Confined compressive strength (□c 0.4 MPa)	≥ 1.5 MPa**
– Strain at failure (unconfined test)	≥ 1%*
– Permeability	< 10^{-8} m/s*

* For acceptance testing a 10-point moving average shall apply

** to be tested only for suitability trial and in case of doubt

6.2.1 Mix Design – Development

Trial tests shall be carried out to specify a mix design for plastic concrete which meets the requirements aforesaid. The maximum grain size shall not exceed 12.5 mm. During construction, the actual composition shall be recorded for each batch of concrete and batching shall not deviate by more than 5% per ingredients.

6.2.2 Concreting – Placing of Plastic Concrete in the Cut Off Trench:

Concrete will be supplied to the trench locations by concrete trucks at a sequence sufficient to ensure a minimum required pouring rate per hour via tremie pipe, sufficient to ensure a minimum rising of the concrete level in the panel of 3 m per hour. The plastic concrete will be poured directly from the truck mixer into the hopper of the tremie pipe string. For panels up to 7M, two tremie pipes shall be used and concrete to be poured simultaneously. During concreting the tremie pipes will be kept continuously immersed in the fresh concrete by a minimum of 3 meters. While the concrete is rising from bottom to top, sections of the tremie pipe string will be removed fulfilling the requirement of a minimum 3M embedment of the bottom of the string into fresh concrete on one side and ensuring constant flow of fresh concrete on the other side.

Concreting will be carried out typically at maximum to top of guide wall in order not to unduly spoil the working platforms with concrete overflow. Some concrete mixed with bentonite slurry may remain within the upper layer of the cut off wall. Any slurry and/or COW concrete remaining within the guide wall perimeter after COW completion will be removed during demolition of the actually existent working platform and guide wall down to the specified depth from the top of existent working platform including the Blinding Concrete. For trimming the wall head while removing the guide walls particular care shall be taken.

https://doi.org/10.36375/prepare_u.iei.a112

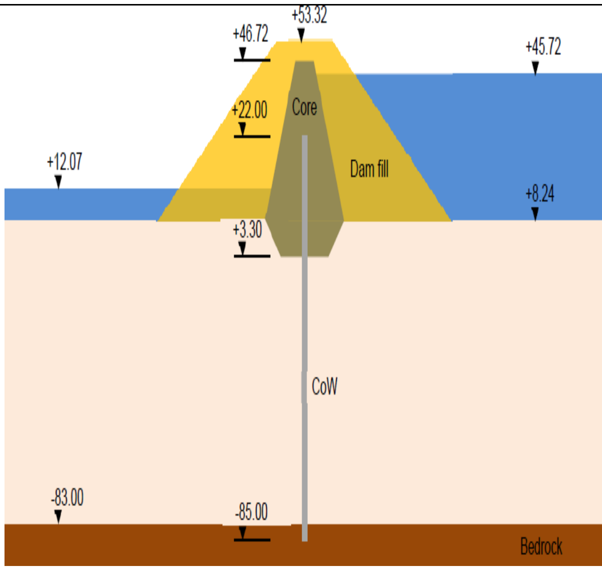

Fig: 11-EARTH CUM ROCK FILL DAM CROSS SECTION

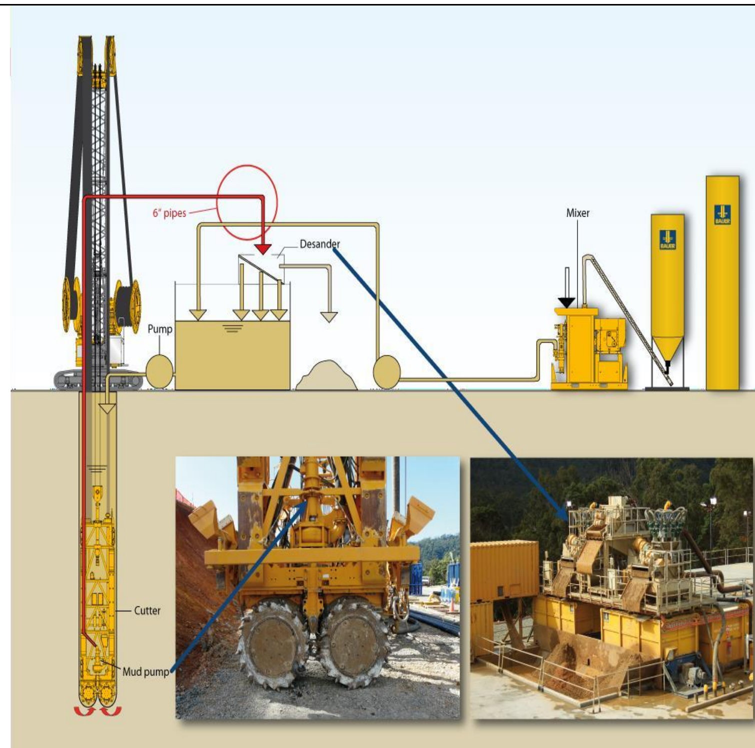

Fig: 12-Cut Off Wall Construction Set Up for ECRF Dam

6.3 Quality Control Management Plan (QCMP):

6.3.1 QCMP will contain all tests and control procedures required for a successful execution of the concrete COW for the Polavaram Dam Project in reference to related codes and standards, including but not limited to:

- frequency quality control tests for materials used for and mixed on the project
- description for sampling and testing of materials
- assurance of COW alignment
- assurance of COW continuity
- fresh and hardened plastic concrete quality tests

6.3.2 Precautions to be taken to avoid unacceptable wall parameters:

Unacceptable wall parameters are-

- Not achieving 2 m rock embedment – Rock embedment – Depth control
- Not achieving top of effective COW at 1.5 m below top of guide wall.
- Not achieving COW continuity – Measures to be taken to ensure the wall continuity and Quality of joints and bottom of trench
- Not achieving minimum COW thickness
- Not achieving permeability requirements in samples of plastic concrete as specified
- Not achieving concrete strength in samples of plastic concrete as specified

6.3.3 Plastic Concrete – Testing for Quality control

Project will perform the following tests on the concrete – the entire Quality control for concrete as per the QCMP for the COW:

- Workability (slump and slump flow)
- Workability time (if needed)
- Unconfined compressive strength (28 days)
- Triaxial stress-strain behaviour (28 days) (in case of doubt)
- Permeability (28 days)
- Erosion resistance is covered by UCS test (≥ 1 MPa; see also ICOLD Bulletin 51, 2.3.8. Erodibility)

The design concrete mix for the Plastic Concrete Cut off Wall (COW) will be approved by Project authorities. The test for quality control of plastic-concrete shall be in accordance with relevant codes / standards together with the tentative acceptance criteria for UCS and permeability. These acceptance criteria may be adjusted based on the results of the mixes the BLT-JV proposes to use. The BLT-JV shall vary the proportions of the mix to achieve the desired strength and deformation properties of the plastic-concrete. All requirements shall be subject to changes after evaluation of suitability trial tests, in agreement with the Engineer

6.3.4 Tolerances:

The minimum wall thickness of 1.5 m for each panel is assured for the entire panel depth by the excavation tools of the equipment used. The guide wall will be built in a way to respect the tolerances as indicated in the Technical Specifications. Setting out of the wall shall be to a Centre-line positioned with a tolerance of ± 50 mm. The guide walls will be installed accordingly. For diaphragm wall installation slight deviation from verticality is system inherent; a tolerance of 0.3% from depth is considered in Y-direction (perpendicular to the COW-axis) which might result in a recess at the panel joints.

6.3.5 Integrity of the Cut-off Wall (COW)

The integrity and continuity of the COW is assured by the method of installation chosen. With the equipment provided each individual panel element will have the specified thickness given by the defined size of the excavation tooling – whether size of the grab or dimensions of the pair of cutter wheels. Positioning of the individual panels and the real overlap between neighbouring panels will be controlled and mapped. Position-control during excavation with cutter-inbuilt inclinometer is cross-controlled with equipment which is equivalent to the Cutter Inclination-System (CIS). Final position control will be with a state-of-the-art sonic-measuring device like Bauer Ultrasonic System or KODEN.

Cleaning of the trench bottom will be executed by the cutter installed high performance pump typically while exchanging working slurry to concreting slurry to clean the contact with the bedrock at the bottom of the Diaphragm wall. A compliance check together with the Engineer will take place at the de-sanding unit checking sand content of the concreting slurry and that no large size cuttings are still pumped from the bottom of the fully excavated panel. The cutter excavated secondary panel assures the best possible contact to the neighbouring primary panels by creating a serrated surface for perfect interlocking. Concreting as per Technical Specification with the approved concrete mix will be controlled during concreting and recorded. Uninterrupted concreting by the tremie-method will assure a continuous monolithic concrete panel of the full cross-section.

7.0 CONCLUSION: The Polavaram Major Dam is an ongoing Irrigation project across Godavari River in Andhra Pradesh has been conceived over 8 decades back in erstwhile MADRAS state and now going to be completed by 2022. The main reason of delay in taking up execution is due to the difficult Geo-technical engineering problems in the of sandy river bed as deep as 60-90 mts below. Eminent international experts viz. Dr Karl Terzaghi, Professor of Soil Mechanics; Dr JL Savage Chief Engineer from USA and Sir Murdole Macdonald, a famous Consulting Engineer (ASWAN Dam) of London have either visited site or imparted technical advice on foundation problems of the project. Finally, the project is becoming a reality with the advent and adoption of modern technology of this century by overcoming the foundation problem of Coffer dams both on upstream and downstream with the adoption of JET**-Grouting** soil stabilization to facilitate construction of main Earth Cum Rock Fill Dam. Similarly, modern technology of **Plastic Concrete Diaphragm** cut off wall beneath Earth Cum Rock Fill Dam was implemented during 2019.This Multipurpose Dam is programmed for completion by 2022 and could make it possible only by adoption of Modern Technology in the difficult project construction scenario. The floods of mighty Godavari River in 2021 season are presently passing over 1.13km long commissioned Spillway of project located on the right flank of main River and simultaneously the Earth Cum Rock Fill Dam (ECRF) is progressing in the main River Course. Thus, ultimately the project is reaping benefits of 2.95 lakh Hectares of new command and stabilizes lower riparian four (4) lakh Hectares of Godavari Delta ayacut under existing Sir Arthur Cotton Barrage at Dowlaiswaram in the downstream. In addition, 960 MW of Hydel Power will be generated adding GDP not only to state of Andhra Pradesh but also that of INDIA.

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