United States Society on Dams

Dams — Innovations for Sustainable Water Resources

22nd Annual USSD Conference
San Diego, California, June 24-28, 2002

Hosted by
San Diego County Water Authority

Organized by the USSD Committees on
Concrete
Construction and Rehabilitation
Environmental Effects

MIEL – I IN COLOMBIA-
THE HIGHEST RCC DAM IN THE WORLD:
SOME PRACTICES ADOPTED TO IMPROVE THE CONSTRUCTIBILITY, QUALITY AND SAFETY

MIEL – I IN COLOMBIA- THE HIGHEST RCC DAM IN THE WORLD: SOME PRACTICES ADOPTED TO IMPROVE THE CONSTRUCTIBILITY, QUALITY AND SAFETY

João Moreira[1] Erlon Arfelli[2] Miguel Peres[3] Francisco Rodrigues Andriolo [4]

ABSTRACT

MIEL – I Hydroelectric Dam, in Colombia, is the highest RCC (Roller Compacted Concrete) Dam in the World , being about 190m in height and with a RCC volume of around 1,700,000m3. RCC placement has reached amounts above 110,000m3/per month and has been kept at a level above 100,000m3/per month in over 5 months.

Different methodologies, processes and details were developed during the planning phase and during construction, regarding:

- System of aggregates processing, in order to obtain all crushed aggregates (fine and coarse) including “filler”, necessary to and required by RCC;
- System of Production and Handling of RCC, with forced mixers and an "all conveyor belt" with an "extra-sized Tower-Belt", for transportation and placement of RCC;
- Details for the GERCC ("Grout Enriched RCC") applied next to the upstream face, as one of the impermeable barrier elements;
- Impermeability system through the Synthetic Membrane applied after Dam body construction, as an additional impermeable barrier element.
- Details of the formwork for the downstream stepped face;
- Details of the fixing system of water-stops.
- Details of the quality control system adopted by the Contractor.

The main objective for using these elements is to enable a reduction in time and seek constructive performance facility and improve quality and safety.

MIEL I HYDROELECTRIC PROJECT

General Description of the Project

Hydroelectric Project Miel I is being built in the State of Caldas, Colombia, at approximately 235 km from Bogota. The installed capacity will be 375 MW, with three Francis turbines of 125 MW each. The Project consists of construction of a RCC Dam, with the incorporated spillway, located downstream of “Rio Moro” mouth at La Miel

[1] Planning and Engineering Manager- Odebrecht SA- e- mail: jmoreira@co.odebrecht.com; site: www.odebrecht.com.br

[2] Construction Manager- Odebrecht SA; e- mail: earfelli@co.odebrecht.com; site: www.odebrecht.com.br

[3] Contractor Manager- Odebrecht SA- e- mail: mperes@co.odebrecht.com; site: www.odebrecht.com.br

[4] Consulting Engineer-Andriolo Ito Engenharia SC Ltda- Rua Cristalândia 181- 05465-000- São Paulo- Brazil- Phone: ++55-11- 3022 5613 Fax: ++55-11- 3022 7069; e-mail: fandrio@attglobal.net; site: www.andriolo.com.br

River. The Project is complemented by a Diversion Tunnel with the cofferdams for Dam construction, the hydraulic circuit for power generation, totally underground rock excavation, composed by the Intake, Tunnel, a Power Station with three main caverns (generation, transformers and oscillation), the cables shaft, airshaft, ventilation, intake and gates, and the draft tunnel, which conducts water back to the river, at approximately 4 km downstream of the dam. The Project is completed by the construction of the bottom outlet tunnels and the valves chamber.

RCC volume		41.000 m3
Dam		
Dam height		188m
Crest width		8 m
Crest length		341 m
RCC Volume		1.730.000 m3
Bedding mortar volume		45.300 m3
Cement		200.000 t
Concrete Works		
Conventional (CVC) concrete volume		86.000m3
Shotcrete volume		15.000m3
Reinforcement		4.500 t
Underground Excavation		
Diversion Tunnel	554m	60.555 m3
Intake Tunnel	335m	10.277m3
Draft Tunnel	4098m	299.705m3
Botton Outlet Tunnel	617m	26.054m3
Power House Access Tuneel	889m	43.163m3
Draft Tunnel Access	854m	34.490m3
Botton Outlet Access Tunnel	655m	30.149m3
Shafts	653m	10.738m3
Power House Hall		109.339m3
Galleries	2450 m	18.501 m3
Total Underground Excavation Volume		**642.972 m3**
Rock Quarry (sterile + useful)		**1.750.000 m3**

CONSTRUCTION RCC DAM METHODOLOGY

Crushing Plant

The Crushing Plant is located at some 900 meters on the right bank downstream of the Dam, having been necessary a earth movement of about 2,000,000 m^3 for its installation. With an installed production capacity of 800 tons/hour, 2 primary crushers and three secondary parallel lines compose it.

RCC Concrete Plant

The Betonmac automatic type concrete plant, with humidity control and controlled by its own software, with nominal capacity of 600 m^3/h, is composed by four mixers of double horizontal twin shaft trees, 4 cement silos with 150t capacity each, and aggregate and sand silos. The four mixers discharge through reversible belts on trucks or on an extractor belt that feeds a chute with 35m3 capacity that in turn, delivers to the RCC transportation

system. To guarantee cement supply, the plant counts on 2 stock silos, one with 1000t capacity and another with 450t, plus 4000t stored in “Big Bags”.

Figure 01- Overall view of the Project Site

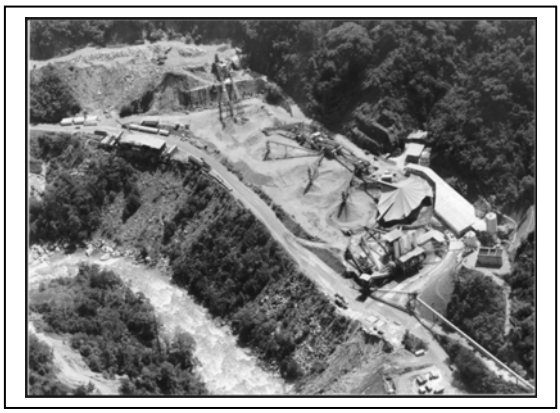


Figure 02- Overall view of the Crushing System

Crushing System	
Primary	
Jaw Crusher Faço 12090	1un
Jaw Crusher Telesmith 44x48	1un
Secondary	
Jaw Crusher Faço 12040	2un
Jaw Crusher Parker 11060	2un
Gyraspheric Crusher Telesmith 6614S	1un
Terciary	
Gyraspheric Crusher Telesmith 52FC	3un
Gyraspheric Crusher Faço 120RAS	1un
Areia	
Impact Crusher Barmac 9000	2 un
Belt Conveyors	1400 m

Transportation System and RCC Placement

Transportation and Placement of RCC (ROTEC System) with a total length of approximately 1,000 m is composed of a set of 7 conveyor belts, a 2,500 Tower Crane (2,500 tm capacity) and a Crawler Placer. The system is designed for a production of 400 m3/h, transporting concrete from the flow regulation chute next to the concrete plant as far as the RCC placement in the dam body. It must be pointed out that for its assembling it was necessary to excavate a 325m tunnel located on the right bank of the river, in a way to assess a platform at the average height of Dam.

Construction Stages

The main construction stages of Dam are the following:

- Excavation and cleaning of flashboards and foundation;
- Execution of the dental concrete in the Dam foundation, of the Tower Crane foundation basis and of placing of the first support pipes of Tower Crane;
- Execution of RCC Dam up to El:291m, concrete handling by dump-trucks;
- At El:291m RCC placement is interrupted to enable complete assembling of Tower Crane and its interconnection with the concrete conveyor belts system;
- Dam execution starting at El:291m using the "All Conveyor System" for handling and placement (Conveyor Belts, Tower Crane and Crawler Placer);
- At El:380m a Jib Peiner VTN 1401 crane will be assembled to give support to the spillway construction and further disassembling and removal of Tower Crane;
- Execution of Dam up to El:450m using the ROTEC System;
- Disassembling of Tower Crane and "All Conveyor Concrete System".

Figure 03- Overall view of RCC Plant

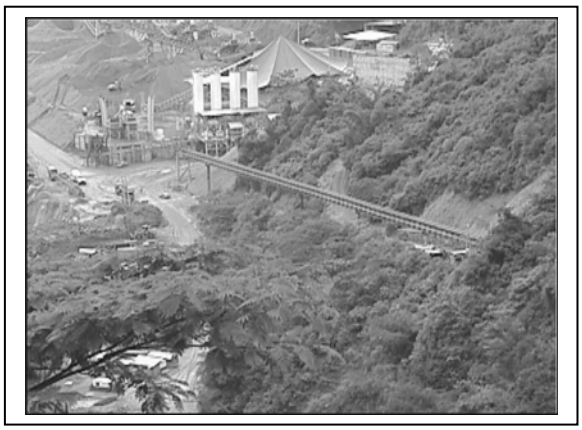


Figure 04- Overall view of the conveyor belts for concrete transportation

RCC Main Activities

RCC Pouring, Leveling and Spreading

RCC pouring is done by 2 bulldozers, in 33cm layers, controlled by a laser level attached to the tractor bulldozer. Equipments used with its respective productivity are:

- Bulldozer CAT D5M 280 m^3/hour
- Bulldozer Fiat-Allis FD-9 180 m^3/hour

Mortar Bedding

Between RCC layers in areas determined by the design and at the contact point of rock foundation before placing a new RCC layer, a very thin mortar layer (10mm thickness) of consistent bedding mortar is applied, which has the purpose of guaranteeing the correct

bonding between RCC layers. This mortar is poured by a agricultural Ford 7610 DT tractor with an attached squeeze, with an average performance of 1200 m^2/hour.

Figure 05- Abutments excavation

Figure 06- River bed excavation of the

Figure 07- Dental concrete on river bed

Figure 08- Tower Belt Crane base

Figure 09- Overall view from foundation

Figure 10- Assembling the Tower Belt

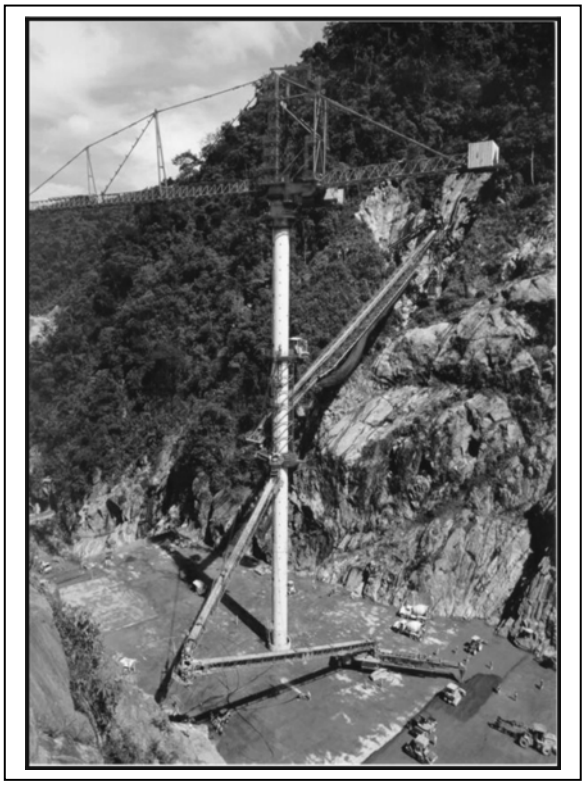
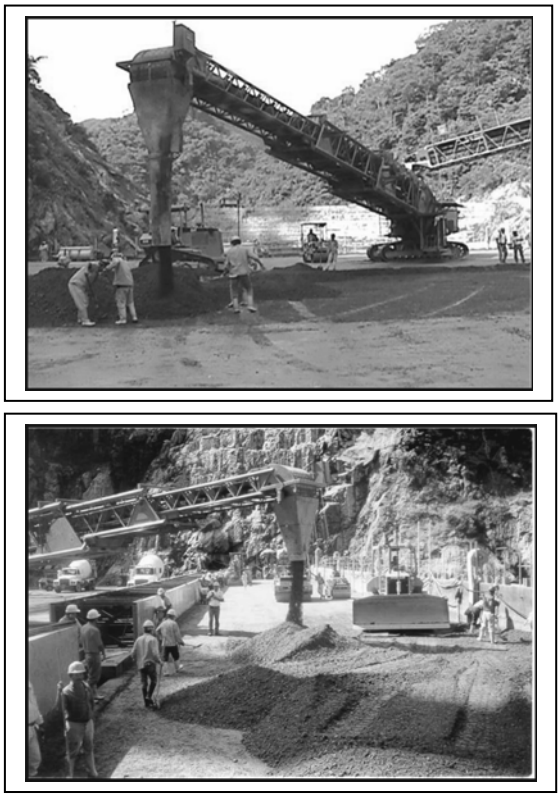


Figure 11- Belts, Tower Belt and Crawler Placer in operation



Figures 12- Details of RCC placement with Crawler Placer

Compaction

Double drum vibrating compactor rollers 11.7-ton type are used, with 6 passes. For finishing in confined areas, 2.5-ton vibrating double drum compactor rollers are used. The equipments used with its respective productivity are the following:

Equipment	Type	Size	Units	Rate
Compactor	Cat 634	11.7 t	02	250 m^3/h (each one)
Compactor	Dynapac CC102	2.5 t	01	Available all period
Compactor	Dynapac 422	2.5 t	01	Available all period

Contraction Joint

A total of 17 transversal contraction joints were designed at the Dam body, with a distance of approximately 17.5m between each. These joints are built through insertion of a 28- caliber “cold rolled” metallic thin plate 26cm high, in the RCC layer already compacted.
This metallic plate is placed with an equipment called Joint Inserter attached to the John Deere 644H loader. Soon after insertion of the plate the joint is sealed with two

repetitions of a 2.5-ton small compactor. The performance for execution of contraction joints is 50m/hour.

Figure 13- RCC placement with Crawler Placer

Figure 14 – RCC spreading and leveling

Figure 15- Bedding mortar delivery

Figure 16- Spreading the bedding mortar

Figure 17- Overall view of RCC pouring

Figure 18- RCC compaction

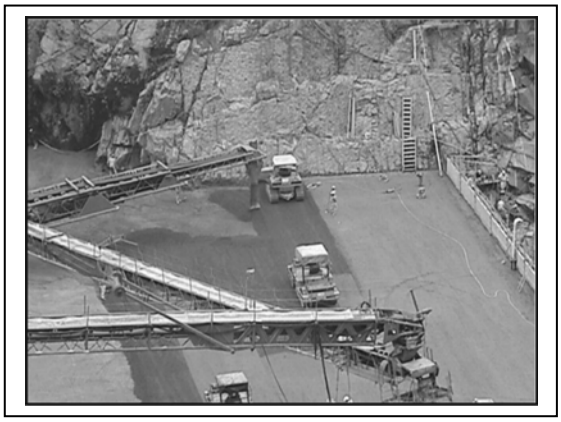


Figure 19- RCC spreading and compaction

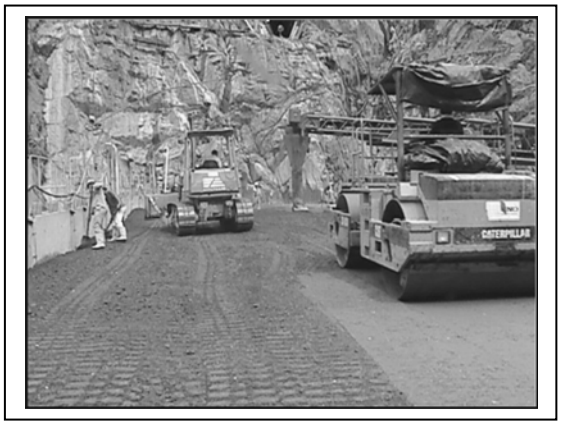


Figure 20- RCC spreading and compaction

Figure 21- RCC compaction in confined zones

Figure 22- Joint inserter and GERCC vibration close the upstream formwork

Grout Enriched RCC- GERCC

The GERCC consists in the application of the cement grout mix over a 40cm RCC strip face upstream of Dam, doing penetration and homogenization through immersion vibrators. The objective of the GERCC is to reduce the permeability at upstream face, performing as an additional protection to the PVC membrane, besides improving surface for installation of it. The cement grout mix has the 0.8 W/C ratio and is prepared with Portland Type I cement in bags, with 1.0% of plasticizer admixture. About 12 liters of grout mix are applied per linear meter of 40-cm strip to be enriched and a 90m/hour performance is obtained, with the staff listed below:

- 1 Foreman
- 2 Vibrator Laborer
- 10 Unskilled Laborer

Construction Joints Treatment

Usually an water-air jet under low pressure is used to clean the RCC surface. Construction Joint treatment with mechanic broom occurs when we have over 36 hours of re-use time for the new layer. The equipment used to start the revolving broom is the John Deere 644H loader and the performance obtained is 1800 m^2/hour.

Figure 23- Metallic plate and Joint Inserter

Figure 24- Metallic plate inserted

Figure 25- Finishing the contraction joint

Figure 26- Overall view at upstream face

Upstream Face – PVC Membrane

The watertightness of upstream face of dam will be provide through a PVC impermeable membrane. During construction of the dam body a series of profiles is placed at previously determined lines that are anchored in the concrete. After dam reaches a certain height, the PVC Membranes are fixed on those profiles composing the sole impermeable surface. At the Miel-I Dam the Carpi System is used, with an impermeabilized area of approximately 31,000 m^2.

Upstream and Downstream Formwork

In the upstream face a climbing formwork type is used, anchored in the already executed concrete, with 2.45m-high panels, and assembled with the help of a crane on tires. The performance for mold placing is 0.67 wh/m^2. The downstream face of the Dam is cast by 60 x 60cm steps. In the execution of that face a very well engineered formwork is used, which enables easy formwork stripping and assembling for the next concrete pouring. The performance for till-up, removal and fixing of these molds is 0.65 wh/ m^2.

Figure 27- Upstream formwork and PVC membrane anchors

Figure 28- PVC membrane installation

Figure 29- Downstream formwork system close view

Figure 30- Downstream formwork system overall view

REMARKABLE RECORDS

The construction methodology and facilities described above, RCC and related works have reached the following records:

- Total RCC Placement in 7 consecutive months : 700,000 m^3
- RCC rate in one month : 118,000 m^3
- RCC rate in one day : 7,300 m^3
- RCC rate in one hour : 408 m^3

Note: Please see the paper- ***"Construction Issues of Miel I Dam- The World's Tallest RCC Dam"***- Marulanda, A.; Castro, A.; Rubiano, N.; published in this Annual Meeting.