SPECIAL WORKSHOP

"CHEMICAL EXPANSION OF CONCRETE IN DAMS & HYDRO-ELECTRIC PROJECTS"

October 18 & 19, 2007

Granada, Spain

Session 2: Chemical Reactions and Processes

Thursday, October 18- 11:00 a.m. – 12:30 p.m

Expansion Effects of Pyrite in the Rock Matrix of the Rio Descoberto Dam

Francisco R. Andriolo, - **Andriolo Ito Engenharia Ltda, São Carlos**

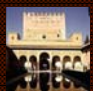
Brazil

CONGRESS DES
GRANDS
BARRAGES
MONTREAL, 2003

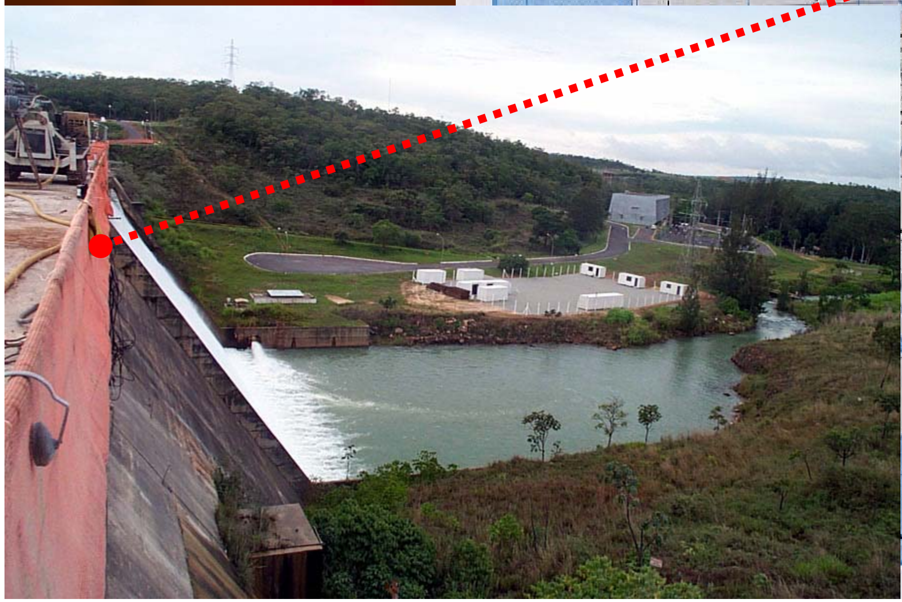
RIO DESCOBERTO DAM:

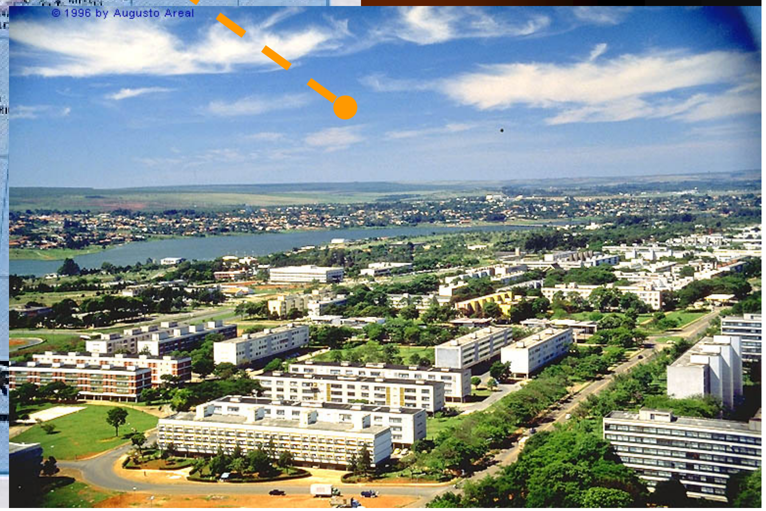
WATER SUPLLY SYSTEM FOR BRASÍLIA CITY- BRAZIL- REHABILITATION AND PERFORMANCE [1; 2; 3]

[1] **Antônio Manoel *SOARES* ; Mércio *VIANA* – CAESB-Cia. de Saneamento do Distrito Federal S/A**
[2] **Nelson L. A. *CORRÊA;* Sabino Freitas *CORRÊA*; Marianne Freitas *CORRÊA* -**
ECL Engenharia e Construções Ltda – Brasília;
[3] **Francisco Rodrigues *ANDRIOLO* -**
Andriolo Ito Engenharia Ltda- São Carlos

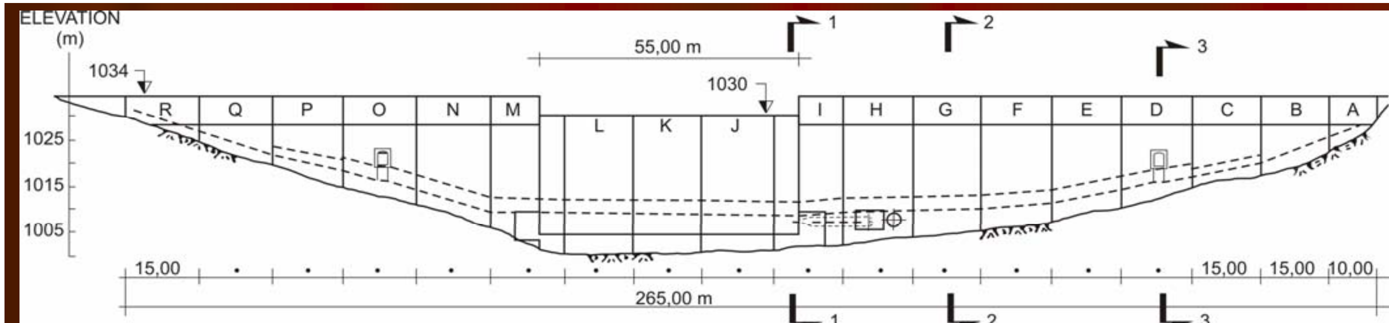


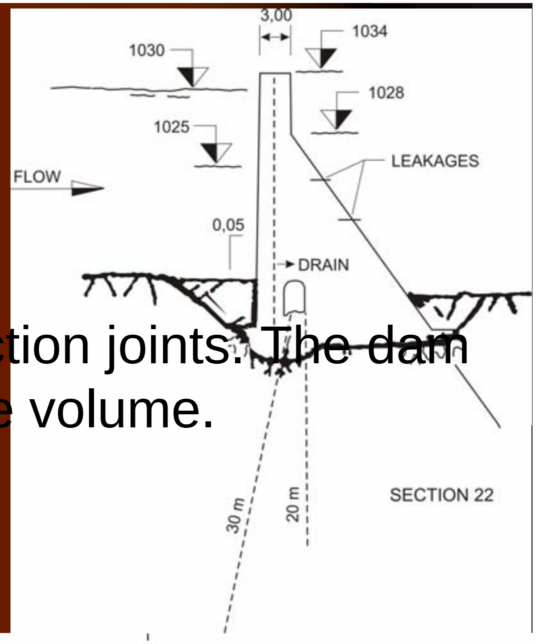
The Rio Descoberto Dam is located about 35 km West side from Brasilia. The Dam is used as a reservoir for the Brazil's Capital (Brasília City) water supply.



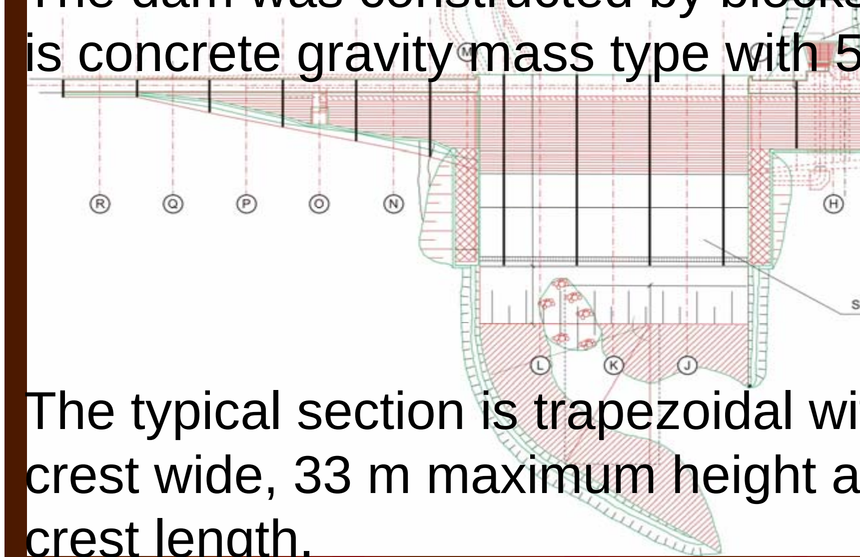


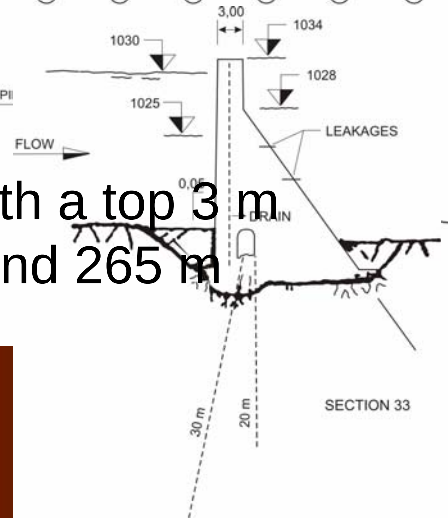
The dam, mass concrete gravity type, was constructed during the years 1971 and 1974.



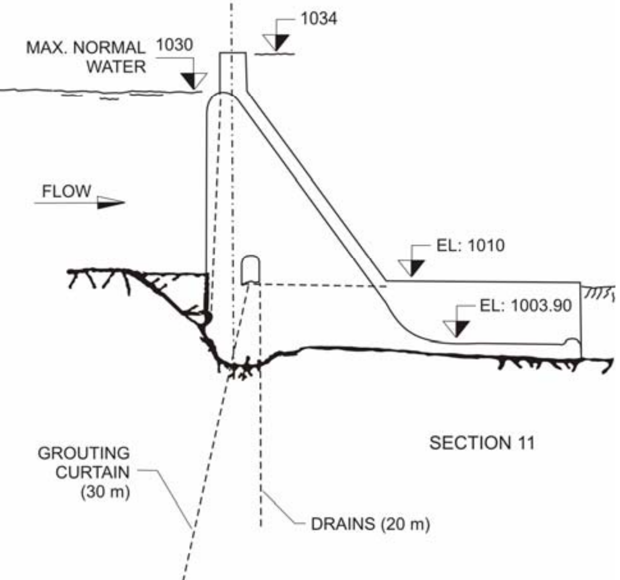


The dam was constructed by blocks, separated by contraction joints. The dam is concrete gravity mass type with 54,500m3 total concrete volume.





The typical section is trapezoidal with a top 3 m crest wide, 33 m maximum height and 265 m crest length.



At the spillway level the reservoir capacity is 1,000,000 m^3 and approximately 60% of the local population water consumption is supplied by the Descoberto reservoir, serving up to 1,200,000 people.

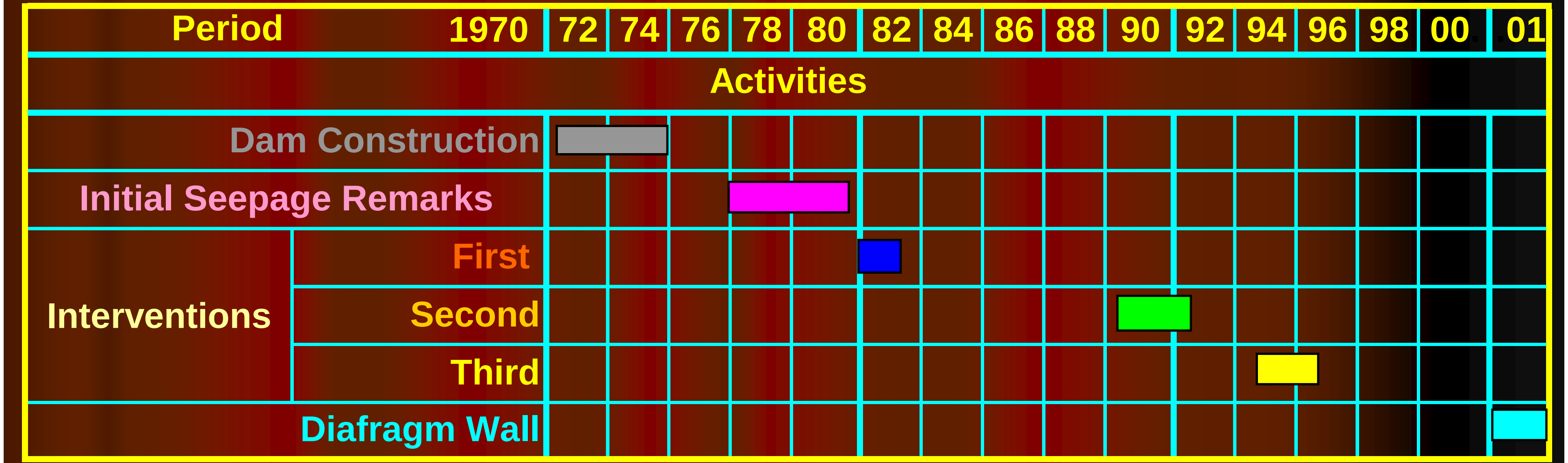
OPENING REMARKS

Some leaching water started to be observed at the downstream face few years after the end of the construction, and filling the reservoir.

Some remedial works were adopted in different periods, as grouting and drainage systems, with no remarkable success. After these remedial works **CAESB** have adopted a new approach looking for the origin of the problems, to adopt a definitive solution. After several analyses, the problem origin diagnosis was the presence of **pyrite in the concrete aggregate (detected by petrographic analysis) combined with the acidic water action (pH< 7).**

The consequences of pyrite composed concrete aggregate was known by the Descoberto Dam designers by the time of construction [01], but the pale local experience with that kind of problems allowed the use of a low level pyrite concrete aggregate in this construction work.

Posterior happenings including the pathologies observed at this dam, and the Fonsagrada Dam [02] report from Spain, demonstrated however, that even very low pyrite levels on hydraulic structures concrete aggregate might cause serious problems

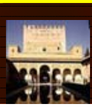


First Intervention

Since the mid 70´s decade leakages were observed at the “I” block’s downstream face. In 1981, as usual in leakage dam treatment method, the first intervention was performed. **The solution was based in epoxy injections applied from the downstream face.**

Second Intervention

Between 1989 October and 1990 July, the second intervention was performed. The works were guided by a preliminary diagnosis report made in 1988. This report indicated construction joints failures as the origin of the problem. These works consisted in the combination of **grout injection filling at the upstream face with internal drainage holes near the downstream face**.



Unfortunately, just three years after the completion of these works, the dam structure was worse than it was before. Right after the completion of these works dam appearance was satisfactory, without leakages at the downstream face and only some weak moisture spots could be observed at the upstream inspection gallery's walls. The inspection gallery was satisfactory and the foundation drains of the dam were operating well.




Third Intervention

In 1993 the Descoberto Dam was presenting serious problems. Moreover than the leaching horizontal planes at the downstream "**E**", "**I**", "**G**" and "**O**" block's face with significant flow, the fissure problem had also increased. At the leaching blocks, new percolating horizontal planes raised. The inspection gallery was flooded and full of carted material from the rock bottom drains.

During the course of this intervention the Owner of the Dam, **CAESB**, decided to adopt a new approach in order to reach the cause of those chronic problems.

At this time a Consultant Committee was, formed by the ***Prof. Dr.Victor de Mello***, ***Eng. Francisco Andriolo*** and ***Eng. Walton Pacelli de Andrade***. The Committee recommended [03] the collection of samples from the inspection gallery drains sediment, dam's concrete, reservoir and drain water analyses.

The analyses indicated [04, 05] the presence of **pyrite** in the concrete aggregate and foundations. The combination of the presence of that mineral with the action of acidic (pure) water, was contributing to the degeneration of the concrete structure of the Descoberto Dam. The main pathologies observed were pyrite reactions [02, 04 to 10].

The adequate solution was to implant a **waterproof barrier, avoiding the contact between the reservoir water and the body of the dam**.

The injection works were suspended and a 4.2m long pilot drive of the diaphragm secant piles wall was built for testing and experience purposes.

OWNER CONDITIONS - SITUATION ANALYSIS

GENERAL

After the three interventions with no successful results, now with a deeper research of the problem developed by the Committee, **CAESB** decided to fully rehabilitate the Descoberto Dam. Starting from the conclusions of the Committee, observing the increase of the structural problems, **CAESB** started to search alternatives for the dam rehabilitation in order to bid the best options.

BASIC REQUIREMENTS

Five basic requests were imposed by the owner for the rehabilitation techniques:

I. The rehabilitation method must prevent the water access to the dam concrete body and foundations;

II. The water supply must be fully maintained during the rehabilitation works;

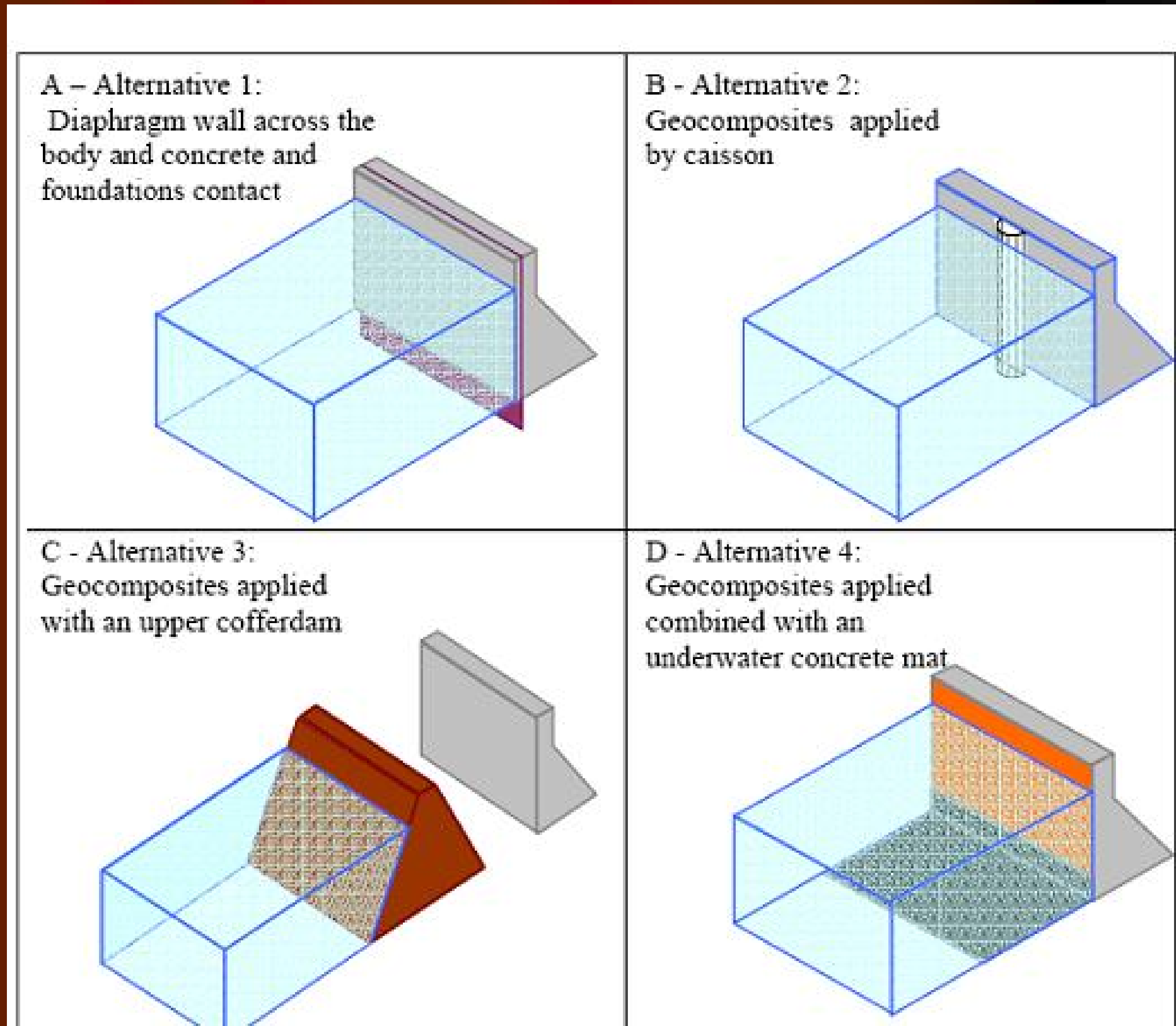
III. The water quality must be fully maintained during the rehabilitation works;

IV. The method efficiency must be possible of being tested by sections during the performance of the rehabilitation works;

V. Grouting based impermeabilization solutions wouldn't be accepted.

AVAILABLE METHODS

After the definition of the owner conditions, four main rehabilitation methods were initially selected. One of these methods was based on the secant pile diaphragm wall experience from 1993 and the three remaining were solutions based in geocomposites barriers application, with some variations, as illustrated below.

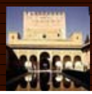


ADOPTED METHOD

GENERAL

The alternatives of application by caissons (**B**) and with the cofferdam (**C**) were excluded, due to the fact that with these two alternatives was impossible to guarantee that the water supply and quality would be fully preserved during the works and these alternatives didn't contemplate the foundation treatment and protection.

After this selection CAESB bid the diaphragm wall and the underwater application geocomposite barrier alternatives. The ECL Engineering Ltd. Contractor won the bid offering the method described by this paper. **The cost of that option was much lower than the underwater application geocomposite barrier option.**

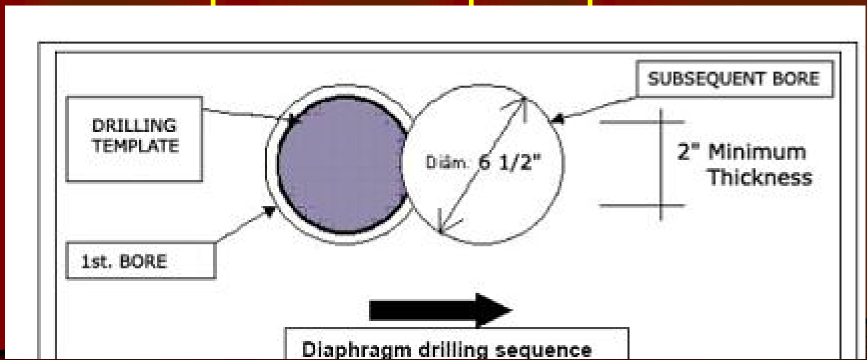


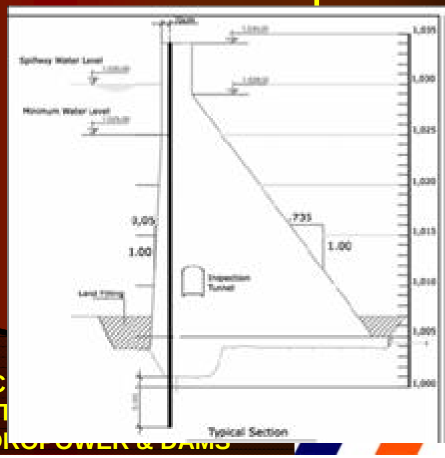
CONCEPT

The process concept is based on the construction of a waterproof secant pile diaphragm wall inside the body of the dam, 70cm far from the upstream face.

The diaphragm was performed from the dam crest without any interference with the reservoir water, need of water level drop or intake obstruction. The secant bores were performed in sequence by drilling equipment with the use of a special guiding template. A drilling sequence composes an up to 2.60m long panel. The minimum acceptable thickness of the diaphragm panels was 2”.

The minimum thickness was mechanically tested and recorded by a VHS underwater system. After the completion of a drilled panel, it was filled by mortar using *“tremie”* system. After the mortar filling of a panel, the last bore of the filled panel is drilled again and this bore starts the next sequence (see Figure bellow). During the drilling process the panels are always filled with water in order to provide equal pressures between the panel and the reservoir.





FIRST EVALUATION

Before the beginning of the diaphragm wall rehabilitation works, several additional tests, analyses, and stability calculations were performed. The scope included permeability, capillarity, compression and shearing tests at samples of the pilot drive of the diaphragm drive built in 1993, collected with rotary drilling probe extractors. Shearing tests at samples extracted from the contact between the diaphragm mortar and the concrete of the dam were also performed, in order to check the adherence between these different materials.

Additional stability analysis were made considering the extreme hypothesis of break of the small dam´s body part between the diaphragm and the upstream face. These calculations were made attending to a **CAESB** concern about the aggressive soluble effects of the soft water of the reservoir, with very low solid suspensions, on the upper part of the dam that would be in contact with the water.

That concern was also dissipated by the evidence that even being in contact with the water, that part has the reactive effects severely decreased after diaphragm insert as a consequence of the end of the reaction renovation and leaching. Laboratory tests have also been made with the mortar mixture indicated by the project designers and performance tests simulating the underwater mortar application conditions, in order to verify the possibility of segregation.

PERFORMANCE AND LOGISTICS

The works were performed by two main groups of activities, drilling teams and mortar underwater application team:

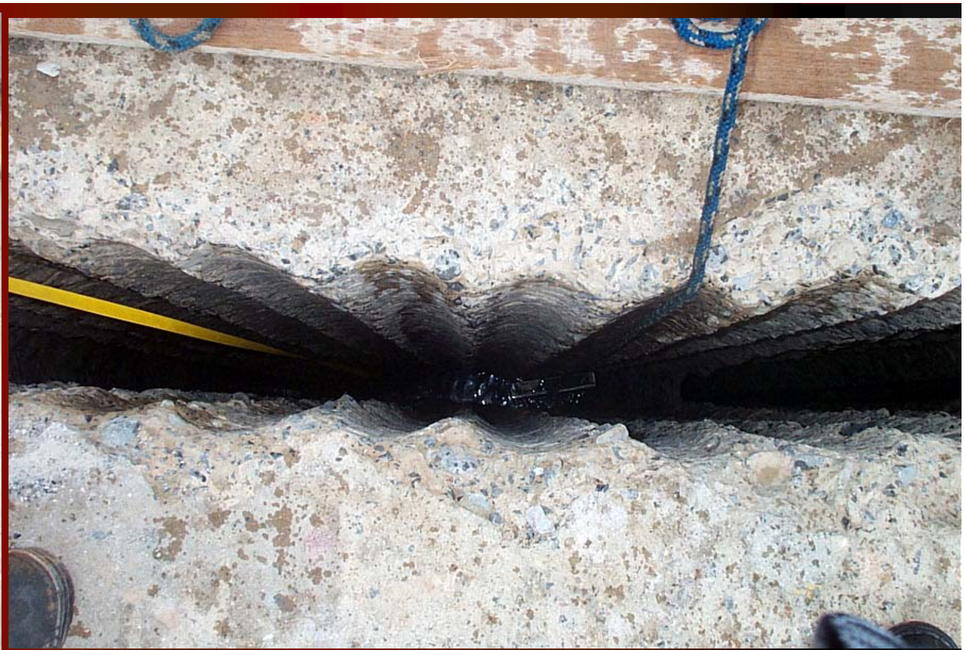
DRILLING

The drilling activities were performed with drilling equipments using DTH (down the hole) hammers, guided by a special alignment template developed for this project. The drilling machinery had to be adapted specifically for the project in order to have the drilling equipment tower aligned at the diaphragm axis.

The project included 70,000 meters of 6” and 6 ½” drilled bores in 18 months of work in two shifts. Midsize drilling equipments were used in the project (with weight between 6 and 11ton). At the peak of production the job site had five drilling machines working at the same time, four at the dam crest and one at the spillway top.

The deepest hole reached 38 m depth, at block “I”, and 22 meters was the average drilling depth of the project.

Boring deviations caused by flexion were minimized by the use of 4” masts.



MORTAR PLACEMENT

The mortar filling was made underwater with “*tremie”* type tube. The work was done from the dam crest. The “*tremie”* pipe was connected directly to the mortar pumping line. The mortar pumping was made from pumps positioned beside the drum mixer parking area at the abutments outside border. In occasions when the pumping distance was longer than 100 meters, two serial disposed pumps were used.

QUALITY CONTROL

WATER QUALITY CONTROL

The water supply for Brasília City, by the Rio Descoberto Reservoir system is made from an inlet at the "**H**" block upstream face. The water is pumped through a 48" welded steel sewer straight for a Water Treatment Plant approximately 5 Km farther. At the Water Treatment Plant inlet the turbidity, coloration and colliform rates at the water are continuously controlled. Those indexes were kept stable during the works. Samples of the reservoir water had also been collected during the project performance and analyzed, including the determination of solid particles in suspension rate. This rate was, in fact, very low, as it is normal in high altitudes. These analyses (performed on samples from different reservoir levels) showed that the quality of the water was not affected by the construction works

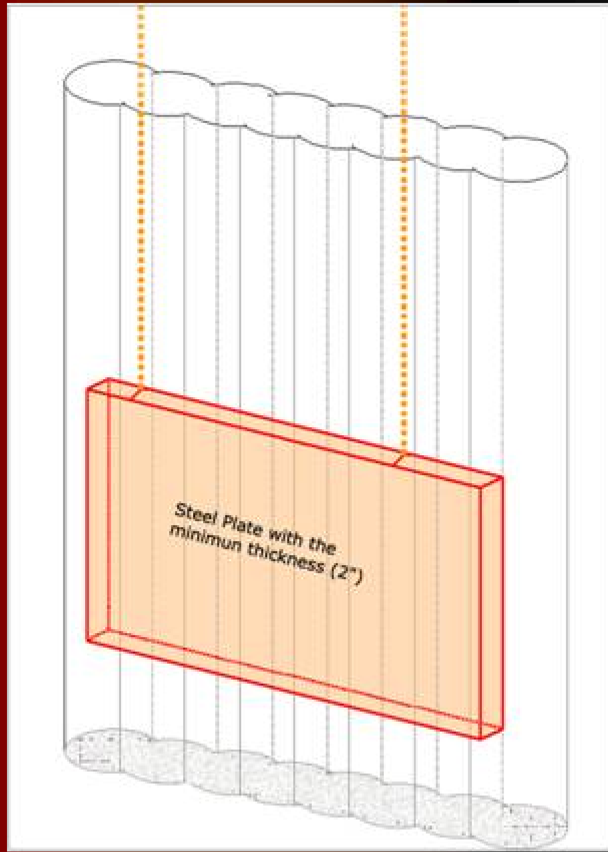
Data	Temp. (°C)	Cor (uH)	Turb. (uT)	pH	Cond. (uS/cm)	Alcal. (mg/l)	CO_2 (mg/l)	DQO (mg/l)	Cloreto (mg/l)	NH_3-N (mg/l)	FeT (mg/l)	ColiT (NMP/100ml)	ColiF (NMP/100ml)	IQA
07/01/1992	25	20	9,60	6,18	11,53	4,1	5,42	1,40	0,10	0,055	0,51	-	-	-
04/02/1992	23	25	8,70	6,28	9,30	2,9	3,04	3,00	0,30	0,080	0,75	900	-	73,0
06/04/1992	26	15	17,00	6,40	9,68	3,6	2,87	1,50	0,90	0,096	0,72	900	240,0	70,6
06/05/1992	23	40	25,00	5,98	10,10	3,2	6,70	1,30	1,05	0,109	1,32	240	50,0	60,0
03/06/1992	23	20	6,90	6,58	9,42	3,1	1,63	1,00	0,84	0,035	0,56	-	-	-
20/07/1992	21	10	3,00	6,42	9,30	3,0	2,26	1,00	0,90	0,030	0,21	50	0,0	85,0
05/08/1992	18	5	2,50	8,00	8,35	2,5	0,10	1,00	1,40	0,030	0,13	500	0,0	76,7
04/09/1992	21	10	1,80	6,66	9,45	3,2	1,40	1,00	0,88	0,034	0,13	70	8,0	85,0
02/10/1992	21	10	3,00	7,30	10,20	2,7	0,30	1,00	0,71	0,030	0,22	300	2,0	84,2
18/11/1992	24	30	18,00	6,43	11,40	2,3	1,70	1,30	1,10	0,177	1,01	1600	170,0	58,7
03/12/1992	21	40	17,00	6,05	1,40	2,4	4,33	2,00	1,80	0,138	0,67	1600	80,0	59,9
05/01/1993	23	40	29,00	7,61	9,60	2,6	0,13	1,50	1,45	0,030	1,71	900	130,0	53,4
02/02/1993	24	40	18,00	6,22	9,83	2,9	3,47	1,20	1,76	0,187	1,09	240	80,0	61,7
04/03/1993	24	40	14,00	7,15	9,19	3,0	0,43	0,90	1,57	0,118	0,94	500	110,0	63,0
22/04/1993	25	40	20,00	7,44	8,94	3,0	0,22	1,70	1,10	0,112	0,00	300	8,0	-
12/05/1993	24	10	9,50	6,77	9,19	2,3	0,78	1,80	0,55	0,065	0,53	-	-	-
15/06/1993	21	20	7,30	6,23	8,21	2,4	2,83	0,90	1,25	0,065	0,52	110	-	74,2
20/07/1993	19	10	4,10	6,75	9,01	3,7	1,32	0,40	1,45	0,046	0,37	80	0,0	79,1
24/08/1993	20	10	3,70	6,43	9,00	3,1	2,30	1,00	1,05	0,038	0,37	240	0,0	78,2
22/09/1993	23	15	3,90	6,34	9,72	3,2	2,93	0,60	1,20	0,070	0,30	80	4,0	79,8
14/10/1993	23	10	3,70	6,32	9,39	3,2	3,06	1,00	1,08	0,030	0,36	50	0,0	81,1
11/11/1993	25	10	4,50	6,18	10,10	4,2	5,55	1,00	0,94	0,030	0,17	-	-	89,8
09/12/1993	25	10	5,00	5,87	10,36	3,0	8,09	0,50	1,35	0,030	0,40	240	13,0	75,1
07/01/1994	19	75	30,00	6,52	9,98	2,8	1,69	1,00	1,55	0,149	1,83	3000	500,0	44,8
04/02/1994	23	25	20,00	6,53	10,60	2,7	1,59	1,50	1,35	0,328	0,83	500	80,0	61,2
03/03/1994	24	40	23,00	6,65	9,54	3,0	1,34	2,00	0,81	0,139	0,79	900	110,0	66,6
07/04/1994	22	100	50,00	6,40	10,28	3,1	2,47	2,70	1,03	0,050	1,78	300	130,0	48,1
06/05/1994	23	50	24,00	6,84	8,66	2,4	0,69	1,40	0,50	0,030	0,58	240	-	70,4
06/06/1994	22	30	10,00	6,54	9,42	2,7	1,56	2,00	1,06	0,069	0,70	240	23,0	69,5
05/08/1994	20	10	3,20	7,00	8,98	2,8	0,56	1,60	0,80	0,030	0,25	30	0,0	87,7
02/09/1994	22	10	2,50	7,20	9,73	2,3	0,29	2,50	0,42	0,047	0,17	27	2,0	89,3
04/10/1994	23	5	1,30	7,40	10,22	4,3	0,34	1,00	0,63	0,030	0,18	30	0,0	89,6
03/11/1994	24	10	3,00	7,10	10,40	4,5	0,71	0,80	0,20	0,030	0,36	-	-	-
14/12/1994	26	15	10,00	7,10	10,95	5,8	0,92	1,00	0,95	0,095	0,46	80	30,0	78,6
11/01/1995	25	15	20,00	7,10	10,43	4,3	0,68	1,60	1,20	0,121	1,04	500	240,0	65,8
16/02/1995	25	30	14,00	7,00	10,10	4,0	0,80	1,50	1,35	0,199	0,70	500	170,0	66,5
21/03/1995	24	25	9,50	6,90	10,70	3,7	0,93	1,40	1,15	0,108	0,52	240	50,0	72,6
18/04/1995	24	20	15,00	6,80	10,18	3,0	0,95	1,50	1,65	0,064	0,83	1400	50,0	65,2
16/05/1995	23	25	12,00	6,90	10,00	2,5	0,60	1,40	1,00	0,161	0,62	50	8,0	75,4
13/06/1995	22	10	5,00	7,00	12,60	2,2	0,40	1,00	1,10	0,037	0,35	70	2,0	80,8
10/07/1995	22	5	3,50	6,90	9,50	2,3	0,60	1,40	0,80	0,030	0,14	13	0,0	89,9
08/08/1995	21	5	10,00	6,90	9,49	1,6	0,40	0,80	0,82	0,030	0,33	50	0,0	83,4
12/09/1995	24	10	3,50	7,20	11,62	3,7	0,47	0,70	1,07	0,053	0,29	7	0,0	87,2
09/10/1995	24	10	3,10	7,04	10,43	3,0	0,50	1,50	0,81	0,070	0,19	8	0,0	90,6
20/12/1995	24	40	33,00	7,10	10,90	3,1	0,50	2,40	1,10	0,461	1,13	140	26,0	63,1
12/01/1996	23	25	20,00	6,90	10,43	2,4	0,60	1,30	0,96	0,141	0,81	32	20,0	74,0
08/02/1996	23	10	7,50	7,10	11,17	3,2	0,50	1,10	1,26	0,128	0,43	14	9,0	81,1
07/03/1996	25	10	5,00	6,6	6,84	2,8	1,40	2,00	0,96	0,088	0,24	13	0,0	86,3
09/04/1996	25	15	10,00	6,70	10,43	3,1	1,20	1,20	0,86	0,058	0,35	90	21,0	81,3
14/05/1996	23	10	4,30	7,20	11,39	2,7	0,34	0,90	0,86	0,089	0,21	0	0,0	95,7
21/06/1996	21	15	3,50	7,60	10,89	3,1	0,16	1,40	0,97	0,061	0,14	23	2,0	85,9
12/07/1996	20	10	2,90	6,90	11,39	3,1	0,78	0,90	0,76	0,104	0,14	0	2,0	97,4
08/08/1996	20	10	3,00	7,60	11,49	3,3	0,17	1,20	1,03	0,030	0,15	-	-	-
06/09/1996		10	5,31	6,70	11,71	3,2	0,52	0,60	0,97	0,067	0,33	17	7,0	85,0
23/10/1996	24	10	10,50	7,10	13,00	3,8	0,60	0,90	1,12	0,113	0,45	500	4,0	73,6
13/11/1996	25	20	15,90	7,30	13,42	3,3	0,83	1,50	0,32	0,122	0,71	240	4,0	69,0
09/12/1996	23	30	28,00	7,20	13,34	3,8	0,80	1,00	1,02	0,122	1,13	300	50,0	64,0
29/01/1997	24	25	24,60	7,00	11,60	3,0	0,60	3,10	1,58	0,162	0,59	90	4,0	69,5
12/02/1997	24	50	27,50	6,50	11,60	3,5	2,20	3,20	0,97	0,043	0,99	700	50,0	60,5
14/03/1997	24	25	15,90	7,50	12,80	3,6	0,23	2,00	0,82	0,070	0,71	170	26,0	73,6
10/04/1997		25	29,20	7,30	12,33	3,9	0,39	1,00	0,76	0,150	1,10	130	22,0	69,5
15/05/1997	21	30	16,90	7,20	12,15	5,0	0,63	1,20	0,80	0,060	0,48	30	7,0	79,9
16/06/1997	21	15	8,60	7,10	11,87	3,2	0,51	1,09	1,60	0,057	0,30	23	0,0	80,8
10/07/1997	21	10	6,24	7,20	13,83	3,1	0,39	0,68	1,15	0,083	0,16	-	-	-
14/08/1997	24	15	3,60	7,48	11,22	3,1	0,21	0,09	1,65	0,030	0,27	23	0,0	83,0
11/09/1997	20	15	2,09	6,79	12,02	3,6	1,17	0,65	0,75	0,020	0,12	0	0,0	97,4
01/10/1997	23	18	5,12	6,63	13,85	6,5	3,70	1,01	0,40	0,020	0,10	50	0,0	87,2
05/11/1997	25	10	4,72	6,79	15,18	4,1	1,33	0,45	0,50	0,020	0,27	240	13,0	83,7
02/12/1997	24	12	10,80	6,55	16,32	4,8	2,70	0,57	0,65	0,046	0,33	140	11,0	81,9
07/01/1998	25	18	10,50	6,53	15,56	4,6	2,50	1,12	0,90	0,052	0,27	23	0,0	84,2
04/02/1998	25	25	39,00	7,32	16,40	3,5	0,40	1,23	1,10	0,067	0,91	500	170,0	63,7
13/02/1998		35	33,40	6,50	17,33	3,6	2,50	1,27	0,85	0,020	0,61	70	30,0	70,9
27/02/1998	25	18	2,77	6,65	11,77	4,0	2,50	1,01	0,95	0,020	0,65	800	110,0	73,8
04/03/1998	24	24	22,00	6,50	17,71	4,4	2,80	1,32	0,80	0,021	0,41	800	220,0	74,4
06/05/1998	25	17	12,00	6,76	17,83	4,0	1,30	0,79	1,00	1,300	0,38	210	17,0	765,0
02/06/1998	22	17	7,51	7,20	17,79	5,5	0,45	1,53	1,05	0,112	0,24	17	0,0	83,6
27/04/1999	24	18	8,00	7,18	16,20	6,5	0,90	1,08	0,62	0,020	0,22	300	13,0	83,0
05/05/1999	23	12	7,92	7,18	15,40	6,3	0,83	0,88	0,91	0,020	0,20	50	2,0	83,8
13/07/1999	18	7	2,23	7,22	13,83	5,8	0,70	0,59	0,35	0,020	0,10	220	0,0	86,0
11/08/1999	21	6	2,20	7,12	15,14	5,8	0,50	0,50	0,75	0,020	0,08	23	0,0	89,6
03/09/1999	22	10	3,42	7,21	15,11	7,2	0,89	2,13	0,75	0,020	0,12	50	0,0	86,9
08/10/1999	24	15	8,80	7,11	18,85	7,8	1,21	1,74	0,50	0,041	0,25	170	33,0	83,0
04/11/1999	24	15	6,86	7,05	19,30	6,9	1,23	1,52	0,95	0,057	0,21	170	7,0	80,9
02/12/1999	24	25	15,00	7,19	17,81	7,3	0,94	2,00	1,00	0,175	0,30	1300	50,0	72,5
05/01/2000	22	25	12,10	7,04	17,48	7,4	1,35	1,50	0,70	0,081	0,31	300	240,0	80,0
02/02/2000	23	22	25,40	6,60	17,81	4,6	2,31	1,89	0,75	0,086	0,51	1300	500,0	71,8
10/03/2000		30	25,90	6,41	16,63	6,4	4,98	3,60	0,80	0,185	0,53	1100	700,0	69,3
17/03/2000	24	40	30,70	6,72	17,96	5,7	2,12	1,80	0,50	0,138	0,36	3000	230,0	69,6
24/03/2000	24	30	20,00	6,68	16,28	5,7	2,38	2,62	0,50	0,048	0,49	1700	230,0	72,0
31/03/2000	24	40	23,80	6,55	17,64	5,4	3,04	2,68	0,70	0,136	0,59	1300	130,0	-
14/04/2000	24	20	12,50	6,59	15,97	6,8	3,50	1,77	0,75	0,136	0,40	130	30,0	79,0
25/05/2000	22	20	7,65	6,86	15,89	4,9	1,35	1,92	0,80	0,172	0,29	80	2,0	83,9
14/06/2000	19	10	6,30	6,50	17,60	4,9	3,10	0,73	0,65	0,042	0,25	50	0,0	86,1
27/07/2000	22	5	3,18	7,18	16,56	4,9	0,65	1,15	1,20	0,024	0,12	2	0,0	90,7
22/08/2000	19	5	3,41	7,14	16,70	5,3	0,77	1,15	1,55	0,020	0,11	0	0,0	90,6
28/09/2000	22	30	3,09	7,10	15,69	5,7	0,92	0,62	1,06	0,020	0,12	300	2,0	81,3
19/10/2000	23	2	2,45	7,00	18,10	5,7	1,14	1,40	1,00	0,020	0,10	16000	2,0	74,8
29/11/2000	23	25	32,60	6,84	21,30	5,3	1,53	3,40	0,80	0,111	0,48	3000	1300,0	65,7
27/12/2000	25	30	15,70	6,93	19,21	6,5	1,53	0,72	1,15	0,245	0,37	300	50,0	77,0
31/01/2001	24	27	14,60	6,59	22,80	7,9	4,06	1,70	1,40	0,131	0,34	2400	9,0	68,5
22/02/2001	24	12	6,97	7,05	20,30	6,2	1,11	1,11	1,25	0,124	0,24	130	17,0	78,3
01/03/2001	24	18	11,90	6,55	21,80	6,1	3,44	1,42	1,40	0,033	0,32	800	800,0	72,7
29/03/2001	25	18	10,30	7,18	22,70	14,9	1,97	1,35	1,05	0,160	0,34	700	70,0	75,2
18/04/2001	24	18	8,10	7,14	22,70	8,3	1,46	1,30	0,75	0,060	0,27	300	80,0	81,2
30/05/2001	22	7	3,09	7,14	20,00	7,1	1,03	2,38	1,15	0,020	0,11	16000	1100,0	72,3
20/06/2001	20	10	3,92	7,59	23,70	7,9	0,41	0,60	1,00	0,107	0,14	130	0,0	82,0
26/07/2001	20	7	2,58	7,39	21,30	9,4	0,77	0,96	0,95	0,020	0,12	500	2,0	80,1
22/08/2001	21	8	2,42	7,20	18,60	7,8	0,98	2,04	0,95	0,020	0,11	230	0,0	81,4
19/09/2001	22	7	2,70	7,27	15,44	7,8	0,84	0,86	0,85	0,143	0,11	2400	30,0	-
24/10/2001	23	7	3,10	7,12	20,20	6,7	1,02	1,21	0,85	0,139	0,11	16000	8,0	75,4
13/12/2001		23	17,10	6,99	20,10	5,1	1,04	3,19	0,95	0,056	0,33	230	80,0	76,0
24/01/2002	24	25	15,90	7,15	18,51	8,3	1,18	2,63	0,90	0,150	0,45	2419	29,2	67,2
26/02/2002	25	30	12,80	6,93	15,65	5,9	1,39	4,83	0,70	0,047	0,40	1733	48,0	72,3
25/03/2002	24	12	10,10	6,75	17,04	7,8	2,77	2,05	0,80	0,208	0,35	2419	138,0	72,7
17/04/2002		18	8,44	7,39	17,09	-	-	1,08	1,15		0,27	387	-	74,5
15/05/2002		12	4,12	6,12	16,47	-	-	1,21	1,25	0,020	0,20	345	-	76,9
19/06/2002		10	3,40	6,54	15,00	-	-	0,87	0,80	0,080	0,20	387	-	83,0
17/07/2002		13	3,08	6,60	15,90	-	-	1,15	1,05	0,020	0,15	345	-	79,3
15/08/2002		7	6,03	6,81	15,08	-	-	0,62	0,90	0,082	0,20	2419	-	73,5
19/09/2002		7	4,80	6,81	16,83	-	-	1,12	0,70	0,041	0,06	2419	-	77,4
16/10/2002		10	3,15	7,08	27,60	-	-	1,40	0,75	0,119	0,24	2419	-	76,7
28/11/2002		12	7,96	6,83	19,95	-	-	1,24	2,10	0,020	0,22	1733	-	63,6
10/12/2002		12	7,13	7,01	20,00	-	-	1,40	1,15	0,197	0,21	2419	-	70,6

Data	Temp. (°C)	Cor (uH)	Turb. (uT)	pH	Cond. (uS/cm)	Alcal. (mg/l)	CO_2 (mg/l)	DQO (mg/l)	Cloreto (mg/l)	NH_3-N (mg/l)	FeT (mg/l)	ColiT (NMP/100ml)	ColiF (NMP/100ml)	IQA
07/01/1992	25,5	15	7,60	6,06	11,24	3,9	6,78	1,30	0,10	0,051	0,38	-	-	-
04/02/1992	23,0	15	4,80	6,53	9,10	2,9	1,71	2,50	0,30	0,085	0,45	220	-	81,2
06/04/1992	25,5	15	15,00	6,50	9,16	3,5	2,11	1,70	0,90	0,055	0,58	1600	300	70,9
06/05/1992	22,5	30	23,00	6,14	9,87	3,0	4,34	1,40	1,05	0,088	1,03	1600	300	61,7
03/06/1992	24,0	20	6,80	6,68	9,42	3,0	1,25	1,00	0,88	0,031	0,49	-	-	-
20/07/1992	21,0	10	3,10	6,44	9,00	3,0	2,16	1,20	0,90	0,038	0,26	110	0	82,8
05/08/1992	18,0	5	2,60	7,89	8,68	2,9	0,07	0,90	1,70	0,030	0,15	900	0	74,8
04/09/1992	22,0	5	2,00	6,69	9,11	3,0	1,21	0,90	0,79	0,049	0,16	80	8	86,7
02/10/1992	21,0	10	2,50	7,77	10,30	3,1	0,10	0,60	0,57	0,034	0,24	300	7	84,0
18/11/1992	24,2	-	-	6,26	9,68	2,4	2,64	1,10	0,92	0,079	0,40	1600	500	-
03/12/1992	22,8	25	13,00	6,08	1,36	2,5	4,23	1,50	1,70	0,064	0,52	300	30	68,5
05/01/1993	22,8	40	30,00	7,85	9,45	2,2	0,06	1,60	1,40	0,030	1,30	900	300	56,9
02/02/1993	25,5	40	15,00	6,56	8,94	2,8	1,53	1,30	1,58	0,148	0,93	23	13	68,7
04/03/1993	25,0	40	12,00	7,40	9,05	3,1	0,25	0,90	1,45	0,108	0,77	130	50	67,4
22/04/1993	25,5	30	11,00	7,70	8,47	2,6	0,10	1,50	1,10	0,062	0,00	1600	7	-
12/05/1993	24,5	10	9,30	7,71	8,81	2,0	0,07	1,70	0,65	0,050	0,41	-	-	-
15/06/1993	21,0	20	6,60	6,26	8,04	2,4	2,64	0,80	1,10	0,060	0,50	50		77,4
20/07/1993	19,0	10	4,20	6,42	9,00	3,6	2,74	0,60	1,50	0,058	0,35	110	0	78,1
24/08/1993	20,0	10	3,30	6,50	9,16	3,2	2,02	1,50	0,90	0,045	0,39	240	0	79,6
22/09/1993	23,8	10	2,50	6,42	9,11	3,0	2,28	0,40	1,15	0,062	0,23	30	2	83,7
14/10/1993	24,0	15	5,10	6,53	9,25	2,9	1,71	1,00	1,13	0,030	0,30	30	4	82,4
11/11/1993	26,0	15	5,00	6,26	10,10	4,3	4,73	1,00	0,94	0,030	0,20	4	-	89,5
09/12/1993	26,0	10	6,30	5,82	9,98	3,0	9,08	1,00	1,26	0,030	0,37	240	13	75,2
07/01/1994	19,0	75	20,00	6,85	9,68	3,1	0,85	1,80	1,50	0,102	1,12	1600	27	54,5
04/02/1994	26,5	20	20,00	6,76	10,10	2,6	0,90	1,50	1,35	0,111	0,64	23	23	74,2
03/03/1994	25,3	30	19,00	6,98	9,38	2,6	0,54	1,90	0,54	0,139	0,49	110	30	76,5
07/04/1994	23,0	100	40,00	6,56	10,22	2,3	1,27	2,50	1,26	0,030	1,62	500	220	47,7
06/05/1994	24,0	50	27,00	6,74	9,98	2,4	0,87	1,60	0,45	0,030	0,45	30	-	76,1
06/06/1994	23,0	25	10,00	6,73	9,73	2,3	0,86	1,30	0,87	0,082	0,54	110	4	76,1
07/07/1994	21,0	20	6,30	6,86	9,63	2,6	0,72	1,70	0,92	0,030	0,42	50	0	80,7
05/08/1994	20,0	10	3,30	7,10	8,83	2,8	0,44	1,50	0,88	0,030	0,28	30	0	86,0
02/09/1994	22,5	10	2,80	7,30	9,37	3,0	0,30	2,00	0,34	0,043	0,25	23	2	89,5
04/10/1994	23,0	5	1,90	7,30	10,95	4,1	0,41	1,10	0,58	0,030	0,18	80	0	87,3
03/11/1994	24,0	10	3,00	7,10	10,07	4,5	0,71	0,60	0,10	0,030	0,28	-	-	-
14/12/1994	26,8	15	8,00	7,10	10,95	6,0	0,95	1,20	0,90	0,086	0,48	70	8	79,3
11/01/1995	25,0	15	15,00	7,10	10,43	4,2	0,67	1,60	0,95	0,100	0,81	240	80	73,6
16/02/1995	25,0	25	12,00	7,00	9,78	3,5	0,70	0,60	1,30	0,225	0,53	240	23	70,1
21/03/1995	25,0	20	9,50	6,90	11,00	3,7	0,93	1,50	1,10	0,097	0,55	240	17	73,0
10/04/1995	24,0	20	15,00	6,70	9,95	2,9	1,16	1,70	1,65	0,057	0,75	130	23	69,4
16/05/1995	23,0	20	11,00	6,90	9,11	2,4	0,60	0,60	0,95	0,089	0,57	240	8	74,4
13/06/1995	22,0	10	4,50	7,00	9,50	2,1	0,40	1,10	1,10	0,040	0,31	50	0	82,1
10/07/1995	21,5	5	3,00	7,00	9,30	2,4	0,50	1,20	0,60	0,030	0,17	17	0	90,0
08/08/1995	21,0	5	10,00	7,10	9,64	1,6	0,25	0,70	0,77	0,030	0,35	22	0	85,8
12/09/1995	22,0	10	3,00	7,20	10,22	3,3	0,42	0,70	1,07	0,046	0,21	30	0	84,6
09/10/1995	24,0	10	3,50	7,20	10,13	2,9	0,40	1,30	0,76	0,066	0,25	14	8	89,6
10/11/1995	24,0	15	7,00	7,40	10,40	2,7	0,20	0,90	0,71	0,076	0,40	-	-	-
14/11/1995	24,0	10	6,00	7,70	10,43	3,2	0,13	1,00	0,81	0,068	0,39	-	-	-
24/11/1995	25,0	15	7,00	6,90	10,63	2,4	0,60	1,00	0,91	0,030	0,38	-	-	-
30/11/1995	21,0	10	7,00	7,00	10,33	2,3	0,46	1,50	0,95	0,036	0,39	-	-	-
20/12/1995	23,0	40	25,00	7,10	10,80	2,8	0,44	2,00	1,20	0,193	1,01	350	90	61,0
12/01/1996	23,0	25	20,00	7,10	9,68	2,6	0,41	1,20	0,96	0,141	0,70	70	0	73,2
05/02/1996	24,0	10	8,50	7,00	10,43	3,0	0,60	1,40	1,11	0,114	0,41	50	2	78,8
07/03/1996	25,0	10	5,30	7,00	10,70	2,9	0,58	1,70	1,01	0,065	0,29	4	0	88,5
02/04/1996	25,0	15	8,50	6,90	10,11	3,1	0,78	1,80	1,03	0,050	0,30	130	9	78,7
14/05/1996	24,0	10	4,00	7,40	11,39	2,7	0,21	0,70	0,81	0,089	0,20	13	0	89,4
21/06/1996	21,0	15	3,20	7,70	10,75	3,0	0,12	1,30	0,97	0,038	0,15	7	0	88,6
12/07/1996	20,0	10	3,10	7,00	11,80	2,8	0,56	0,90	0,70	0,045	0,15	23	2	89,5
08/08/1996	21,0	10	2,80	7,80	11,56	2,9	0,09	2,20	1,03	0,030	0,17	-	-	-
06/09/1996	20,5	10	5,11	7,20	11,72	3,0	0,39	1,00	0,77	0,073	0,31	2	0	93,7
23/10/1996	24,0	10	10,00	7,20	10,60	3,7	0,47	1,00	1,17	0,140	0,32	80	7	78,6
13/11/1996	26,0	20	13,00	7,40	13,38	3,7	0,29	1,40	0,32	0,125	0,61	70	4	73,0
09/12/1996	23,0	30	28,60	7,20	13,17	3,4	0,40	1,10	1,07	0,072	1,02	170	30	66,0
29/01/1997	25,0	15	18,00	7,40	10,85	3,0	0,24	2,80	1,33	0,145	0,32	80	2	75,4
12/02/1997	26,0	50	20,10	6,80	10,89	3,3	1,04	3,00	1,02	0,030	0,89	500	110	62,6
14/03/1997	25,0	25	14,30	7,40	13,00	3,8	0,30	1,60	0,77	0,066	0,68	80	11	76,6
09/04/1997	20,0	25	27,50	7,50	12,26	3,6	0,23	1,90	0,71	0,150	1,09	900	170	66,8
15/05/1997	21,0	30	15,70	7,30	12,15	4,1	0,41	0,88	0,65	0,056	0,47	30	13	80,7
16/06/1997	21,0	15	8,30	7,20	11,77	3,1	0,39	1,09	1,40	0,057	0,32	9	0	82,6
10/07/1997	21,0	10	5,46	7,10	13,00	3,0	0,48	0,57	1,10	0,090	0,17	-	-	-
14/08/1997	24,0	15	3,70	7,47	11,37	3,0	0,20	0,97	1,60	0,030	0,28	23		83,0
11/09/1997	22,0	15	2,14	6,72	11,49	3,5	1,33	0,70	0,75	0,020	0,10	13	0	90,1
01/10/1997	24,0	12	4,13	6,95	11,32	6,7	1,30	0,57	0,40	0,020	0,08	80	2	87,1
05/11/1997	26,0	10	4,65	7,35	15,08	4,2	0,38	3,83	0,50	0,020	0,24	23	2	87,8
02/12/1997	24,0	10	8,78	6,61	28,50	4,7	2,30	0,56	0,65	0,047	0,29	130	2	82,9
07/01/1998	25,0	18	7,80	6,98	15,21	4,7	1,00	1,04	0,90	0,025	0,20	300	2	74,0
04/02/1998	25,0	20	18,30	7,52	16,96	3,5	0,30	1,17	0,85	0,087	0,51	26	11	79,7
13/02/1998	-	22	18,20	6,98	21,80	3,4	0,60	1,82	0,90	0,020	0,36	130	30	77,4
27/02/1998	26,0	7	1,48	7,35	9,44	4,0	0,50	0,92	0,95	0,030	0,85	9000	1100	68,2
04/03/1998	25,0	24	23,10	6,59	17,78	4,3	2,20	1,30	0,75	0,021	0,49	2400	80	71,5
06/05/1998	25,0	15	12,80	6,84	21,60	4,0	1,30	0,64	2,20	0,167	0,35	800	13	69,2
02/06/1998	22,5	17	7,68	7,39	18,02	5,0	0,41	1,49	0,80	0,151	0,23	80	2	83,6
27/04/1999	24,5	18	8,14	7,18	18,45	6,2	0,80	1,00	0,57	0,020	0,22	230	4	83,4
05/05/1999	23,4	12	7,73	7,21	15,43	5,5	0,68	1,19	0,96	0,020	0,21	14	0	85,7
13/07/1999	17,9	7	2,06	7,26	13,52	5,8	0,64	0,96	0,45	0,020	0,11	23	0	90,5
11/08/1999	20,8	7	2,35	7,15	15,15	5,9	0,80	0,42	0,75	0,020	0,08	4	0	93,6
03/09/1999	22,4	10	3,60	7,39	14,31	7,0	0,57	1,88	0,90	0,020	0,14	13	0	87,7
08/10/1999	24,0	12	7,25	7,29	20,39	8,0	0,82	1,90	0,50	0,037	0,22	170	2	83,8
04/11/1999	25,0	15	5,82	7,13	20,20	7,0	1,04	1,84	1,00	0,020	0,16	300	0	79,9
02/12/1999	24,0	20	9,57	7,39	17,47	7,5	0,61	1,99	1,00	0,112	0,22	110	26	80,1
05/01/2000	22,0	30	10,50	7,13	17,30	7,3	1,08	1,42	0,70	0,119	0,29	500	130	78,3
02/02/2000	24,2	18	15,10	6,86	20,36	4,5	1,24	2,55	0,75	0,027	0,36	1600	27	75,5
10/03/2000	-	20	12,10	6,84	15,27	6,2	1,79	1,62	0,75	0,136	0,34	1100	170	77,4
17/03/2000	24,5	24	15,70	7,13	17,42	5,3	0,79	1,98	0,50	0,170	0,46	9000	1300	70,5
24/03/2000	24,8	25	13,40	7,02	17,14	5,7	1,09	1,69	0,50	0,020	0,43	500	27	80,2
31/03/2000	25,1	20	13,40	7,09	16,80	5,9	0,96	2,30	0,80	0,139	0,41	500	90	-
14/04/2000	25,0	15	10,50	6,72	16,46	7,3	2,78	1,85	0,70	0,134	0,32	170	23	81,0
25/05/2000	21,9	20	8,06	6,89	15,97	4,8	1,24	1,78	0,80	0,142	0,26	70	0	83,6
14/06/2000	19,0	10	6,45	6,75	29,20	5,2	1,85	0,83	0,65	0,041	0,22	30	0	87,7
27/07/2000	22,0	8	3,36	7,23	17,25	4,9	0,58	1,05	1,15	0,034	0,14	23	2	84,5
22/08/2000	20,0	5	3,26	7,05	16,37	5,2	0,93	0,90	1,20	0,020	0,12	0	0	92,9
28/09/2000	22,3	12	3,59	7,05	15,90	6,1	1,09	0,64	0,95	0,020	0,12	230	0	81,2
19/10/2000	23,4	4	2,82	7,40	18,87	5,7	0,45	1,32	0,95	0,020	0,10	300	7	81,1
29/12/2000	23,9	18	13,60	7,08	18,59	5,0	0,83	2,40	0,55	0,107	0,24	1300	500	77,8
27/12/2000	25,8	19	10,40	7,08	19,07	5,5	0,91	0,95	1,15	0,256	0,24	240	8	74,8
31/01/2001	25,5	15	10,00	7,66	27,80	8,3	0,36	1,63	1,45	0,155	0,26	5000	2400	68,1
22/02/2001	25,4	12	5,53	0,87	19,19	5,6	1,51	1,26	1,20	0,135	0,22	240	8	77,8
01/03/2001	24,0	15	7,30	7,00	21,60	6,0	1,20	1,75	1,50	0,053	0,24	230	17	75,8
29/03/2001	26,6	18	10,40	7,16	22,90	9,9	1,37	1,86	1,25	0,158	0,30	800	22	69,8
18/04/2001	24,6	18	8,63	7,59	-	-	-	1,49	0,75	0,030	0,30	500	8	77,2
30/05/2001	22,7	12	3,19	7,20	21,80	7,5	0,95	2,67	1,15	0,020	0,14	2400	500	75,5
20/06/2001	21,0	10	3,38	6,93	21,00	7,6	1,79	0,53	1,05	0,102	0,13	34	0	84,5
26/07/2001	20,4	10	2,45	7,26	18,12	9,2	1,01	0,84	1,10	0,050	0,10	220	0	81,0
22/08/2001	21,0	8	2,31	7,13	17,69	7,6	1,13	1,30	0,90	0,020	0,09	500	2	81,3
19/09/2001	22,0	7	2,66	7,19	14,82	8,1	1,05	0,88	0,85	0,114	0,11	240	50	82,4
24/10/2001	23,0	10	3,81	7,39	21,00	6,7	0,55	1,04	0,95	0,151	0,11	500	50	79,4
13/12/2001	-	18	10,70	7,10	19,22	5,2	0,83	2,36	0,80	0,123	0,21	130	13	82,2
24/01/2002	25,0	25	11,50	7,16	18,33	7,9	1,09	1,71	0,75	0,131	0,32	2419	20	72,9
26/02/2002	25,0	25	8,79	7,12	16,03	5,8	0,88	4,39	0,65	0,039	0,32	1203	8	77,1
25/03/2002	24,0	7	8,45	6,88	16,53	6,0	1,58	1,24	0,85	0,195	0,32	2419	128	72,5
17/04/2002	-	15	6,37	7,64	16,27	-	-	1,55	1,10	0,101	0,27	261	-	78,7
15/05/2002	-	12	4,02	5,98	17,29	-	-	1,61	1,10	0,080	0,20	579	-	77,4
19/06/2002	-	8	3,24	6,62	14,49	-	-	0,92	1,05	0,023	0,12	236	-	80,1
17/07/2002	-	10	2,17	6,80	15,07	-	-	0,89	0,85	0,029	0,15	2419	-	79,2
15/08/2002	-	7	3,07	7,20	14,67	-	-	0,59	1,09	0,070	0,13	2419	-	73,5
19/09/2002	-	7	4,51	6,92	16,69	-	-	1,04	1,00	0,020	0,04	2419	-	74,6
16/10/2002	-	9	2,73	7,08	27,60	-	-	1,69	0,75	0,180	0,15	1414	-	80,2
28/11/2002	-	12	6,54	7,24	18,35	-	-	1,45	1,90	0,020	0,16	1733	-	72,1
10/12/2002	-	12	6,27	7,18	18,81	-	-	1,27	1,10	0,184	0,24	2419	-	71,4

PROCESS CONTROL

Diaphragm Continuity

The continuity of the diaphragm panels was controlled by mechanical testing and underwater VHS video system. The mechanical test was made by letting down a steel plate with the minimum diaphragm thickness allowed. In case of persistence of doubt after the mechanical test, the VHS underwater camera was used to inspect the suspect drive. This video system was also used to check and register the contact between different drives

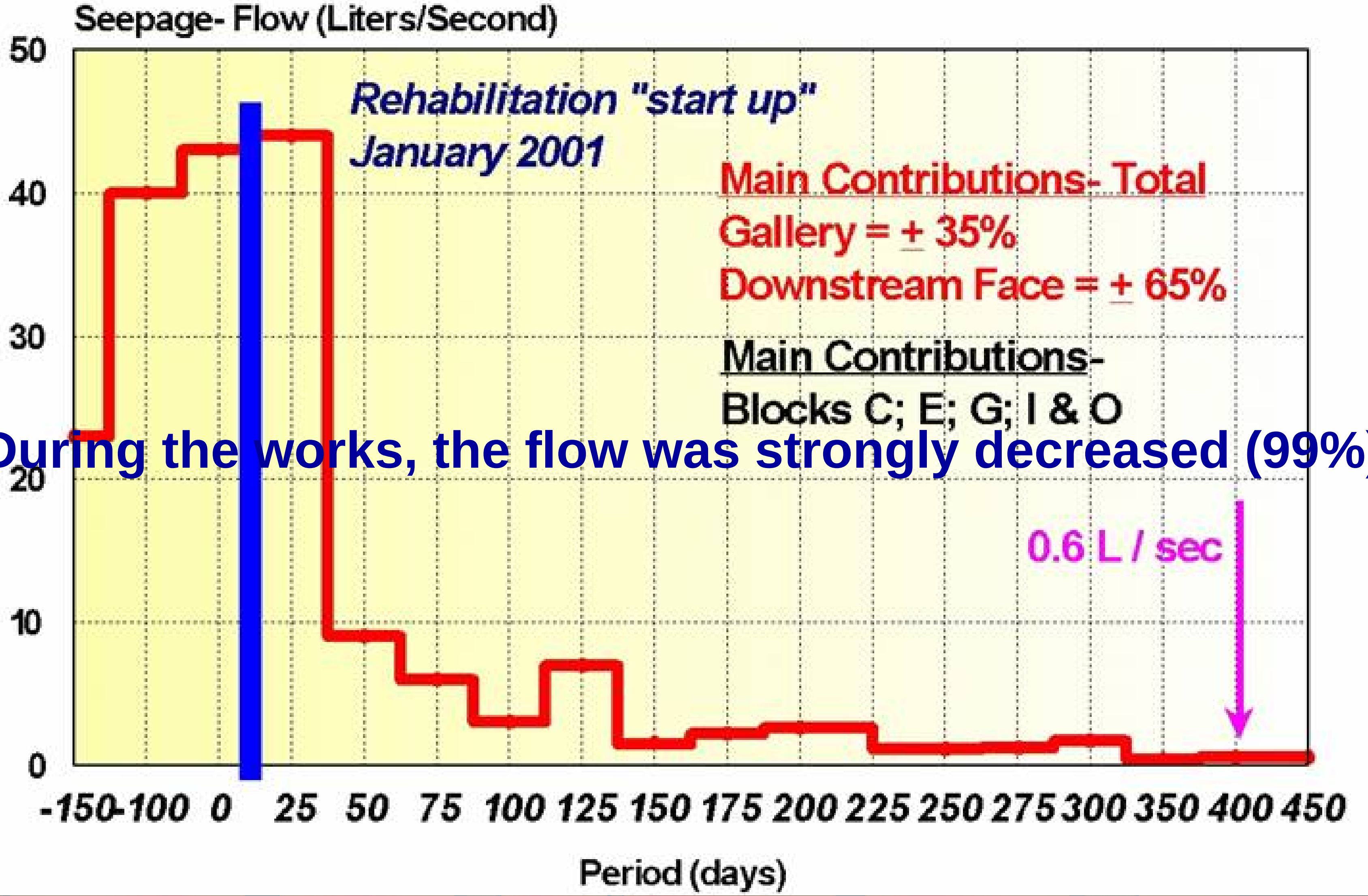


Water Losses Flow Control

Since the beginning of the works, the downstream face and inspection gallery water loss flows were controlled.

Rio Descoberto Dam - CAESB - Brasilia- Brazil

Water Seepage (liters/sec)= Gallery + Downstream Face



During the works, the flow was strongly decreased (99%).

Mortar Drilled Cores Tests

Cores were drilled from the mortar placed in the diaphragm and tested. The following statistical data were obtained:

Property	Mortar (diaphragm)	Interface Concrete (dam)- Mortar (diaphragm)	Concrete (dam)
Absorption (%)	1.22		
Specific Weight (t/m3)	1.97 – 2.08		2.52
Permeability (m/s)	$10^{-11} - 10^{-10}$		
Compressive Strength (MPa)	12.7 – 31.1		25.7
Splitting Tensile Strength (MPa)	1.87	1.14	4.51
Direct Tensile Strength (MPa)	1.07 – 1.80		2.32
Shear Strength (MPa) under Normal Pressure: 2.0 MPa	2.77 – 5.57	2.05 – 3.77	5.03 – 5.14
Shear Strength (MPa) under Normal Pressure: 4.0 MPa	3.92 – 6.63	3.10 – 3.66	6.43 – 6.76
Shear Strength (MPa) under Normal Pressure: 6.0 MPa	5.57 – 8.38	4.50 – 6.10	12.42

Figure 21- Statistical data from drilled cores

The methodology adopted for the Rio Descoberto concrete dam rehabilitation was successful to reach the following purposes:

- ☺ Less expensive offer;
- ☺ Guarantee the water supply in terms of quantity (no interruption) and quality;
- ☺ Reduce the water leakage to a normal-accepted amount;
- ☺ Rehabilitate the dam structural safety

REFERENCES

[01] – PETRUCCI, ELADIO ENG.;BASÍLIO, FRANCISCO ASSIS PROF.- ***"Estudo da influência da Pirita nos agregados calcareos para a Barragem do Rio Descoberto"***, Geotécnica , Brasília, 12/1972,CAESB.

[02]- GUERREIRO, M., FERNANDEZ CUEVAS, R., GUERREIRO, MA.J., GOMEZ LAA, G.- ***"Causes of failure of the Fonsagrada Dam"***- ICOLD- XVII Congress on Large Dams- Vienna (1991)- pp. 49- 63;

[03]- MELLO, VICTOR F.B. PROF. DR. PHD., ANDRIOLO, FRANCISCO RODRIGUES ENG., PACELLI, WALTON ENG- ***"Visits and Technical Recommendations for the Rio Descoberto Dam"***,-, Brasília, Brazil, April & June/1993,CAESB;

[04]- SIGOLO, PROF. DR.; ASSUMÇÃO, J.C.B, GEOLOGIST - ***"Relatório referente a análise de sedimentos G (Galeria) e R (Reservatório) visando caracterização mineral"***- São Paulo, 06/1993, CAESB;

[05]- SIGOLO, PROF. DR.; ASSUMÇÃO, J.C.B, GEOLOGIST- ***"Análise de amostras da Barragem do Rio Descoberto"***, São Paulo, 02/1995, CAESB

[06]- LEA, FREDERICK, M.- ***"The Chemistry of Cement and Concrete"***- 3rd Edition- Edward Arnold Publishers Ltd- Great Britain- 1970, pp.568-569

[07]- ***"Exposure of Dam Concrete to Special Aggressive Waters"*** – ICOLD Bulletin 71- 1989- pp 19- 33;

[08]- ***"Durability of Concrete Construction"***- American Concrete Institute- pp. 81- 85;

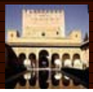
[09]- CÁNOVAS, MANUEL FERNÁNDEZ- ***"Patologia e Terapia do Concreto Armado"***- Editora Pini- São Paulo- Brazil- 1988- pp.37- 245;

[10]- NEVILLE, A. M.- ***"Properties of Concrete"***- 2nd Edition- Halsted Press- John Wiley & Sons Inc. New York- 1973. pp.- 134- 137;

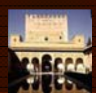
[11]- ***"Recuperação da Barragem do Rio Descoberto- Histórico Sucinto- No. 2"***- CAESB- 01/1999;

[12]- MELLO, VICTOR F.B. PROF. DR. PHD., ANDRIOLO, FRANCISCO RODRIGUES ENG., PACELLI, WALTON ENG- ***"Visits and Technical Recommendations for the Rio Descoberto Dam"***,-, Brasília, Brazil, December/1999,CAESB;

[13]- PACELLI, WALTON , ENG.; BITTENCOURT, RUBENS M.,ENG., ALBUQUERQUEM ALBÉRIA CAVALCANTI, ENG. MSC- ***"Ensaios com Testemunhos de Argamassa e Concreto"***, Laboratório de Furnas 06/2001, CAESB.



Muchas Gracias y Buena Suerte a TODOS !!!



Andriolo Ito Engenharia

Francisco Rodrigues Andriolo

Andriolo Ito Engenharia Ltda
Av. Dr. Paulo Pinheiro Werneck 850- Parque Santa Mônica
13.561- 235- São Carlos- SP- Brasil
Fone: ++55-16- 3307 6078 Fax: ++55-16- 3307 5385

e-mail: fandrio@attglobal.net site: www.andriolo.com.br