ROLLER COMPACTED CONCRETE DAMS

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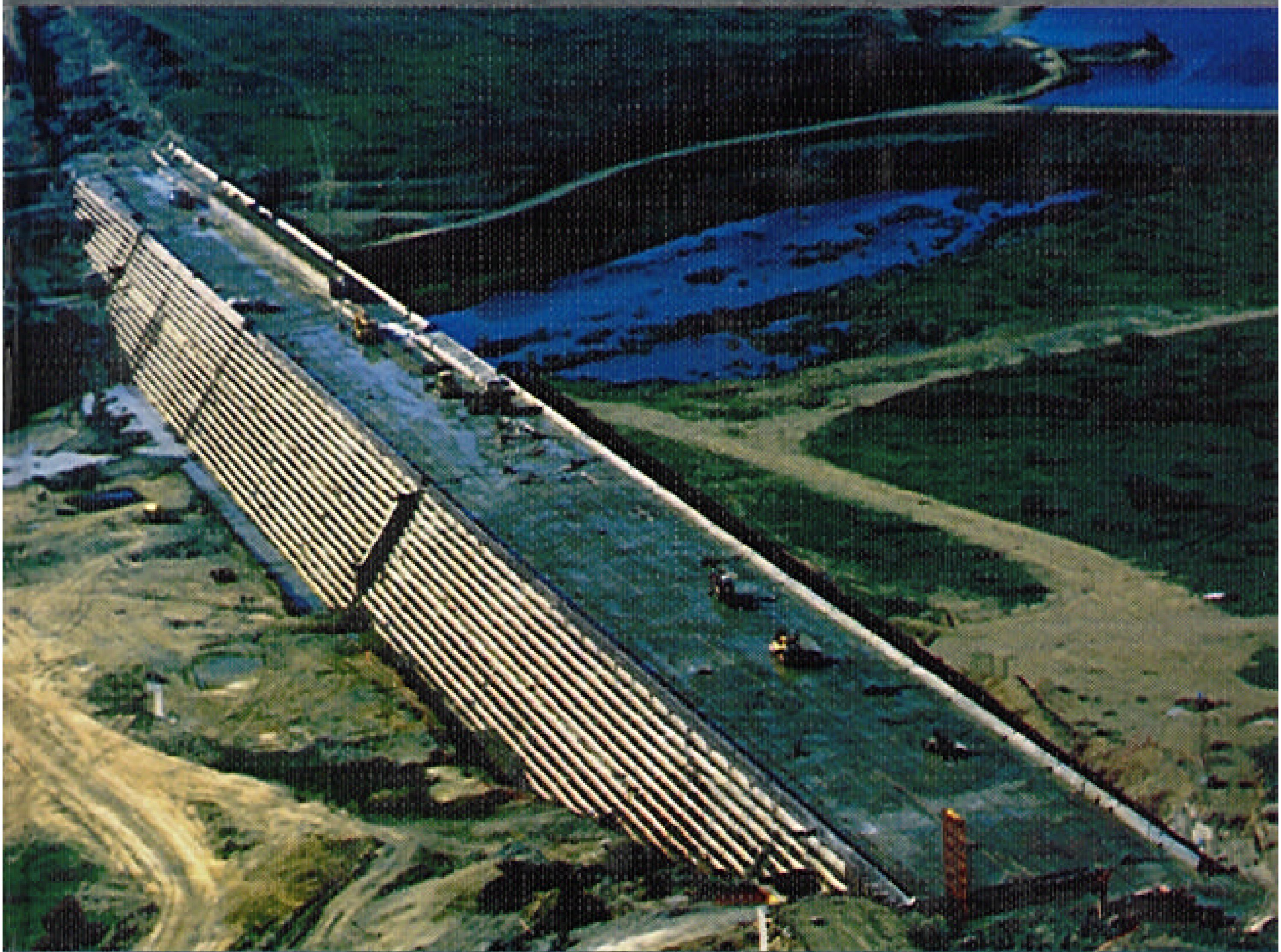
JORDÃO RIVER DERIVATION DAM - FOUNDATION CONDITIONS FOR PLACING THE RCC



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JORDÃO RIVER DERIVATION DAM -

FOUNDATION CONDITIONS FOR PLACING THE RCC

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ABSTRACT

The Jordão River Derivation Dam makes up part of the Segredo Hydroelectric Power Development built along the Iguaçu River, about 280 Km southwest of Curitiba, the capital of the State of Paraná, Brazil [1]. The most important data regarding the Jordão Dam can be summarized as follows:

- A derivation tunnel extending 4,704 m from the Jordão River to the Segredo reservoir, and
- A Roller Compacted Concrete dam, 95 m high with a volume of 570,000 m^3.

The geology of the area is typical of the basaltic rocks in contact with flowing water dividing a slightly columnar basalt with some weathered joints covering the "Breccia" layer and basalt mass. Rounded and very deep cavities have been discovered in the areas where the weathered "Breccia" material is extracted. On the bed of the Jordão River uncommonly deep erosion has been observed, which has been dealt with as described in this report.

1- INTRODUCTION

The construction of a RCC Dam may be executed within a relatively short period of time when availing the advantages provided by such method.

Although, on the other hand, a great deal of time may be necessary to prepare the works and treatment of dam foundations. Such time may be absorbed by unexpected or by under estimated difficulties or yet, due to emergencies that may occur.

The purpose of this paper is to report the procedures adopted, the steps taken and to discuss the traditionally established routines while forewarning about carefulness to be observed for foundations plan.

2- CHRONOLOGY

Topographic and geology field studies for the implementation of the Jordão River Derivation Dam were mainly developed during the following periods:

- Aerophotogrammetry works 1988
- Execution of geological survey trenchs and shafts .... between March and May 1991
- Core drilling and samplings.. between July and November, 1992

In September 1993, it was issued the Invitation Notice concerning the International Bidding for Construction.

Complementary geological and topographical studies, executed in February 1994, lead COPEL - Companhia Paranaense de Energia to displace approximately 25 m the Dam Axis to the upstream. Such displacement resulted from the following basic reasons:

- Occurrence of depressions and rock scouring at the base of the water-falls, detected from bathymetric surveys;
- Reduction in the concrete volume, because at the depression positions Diversion Galleries were planned;
- Reduction of the dam length resulting from most favorable topographic conditions at the right abutment.

3- GEOLOGICAL ASPECTS

3.1- General

Base and acid rocks from the Mesozoic volcanic flow occur in the Jordão River Basin, corresponding to the Paraná Sedimentary Basin.

Normally, basalts are massive, ranging from fine to median, colored dark or medium gray and presenting vesicle-amygdale zones and also basalt Breccia at the intraflow contact.

Acid rocks represent an upper volcanism stage, but not final, and occur at the characteristic plateau of the region. These rocks have light or medium gray color. Texture is highly porphyritic where feldspar crystals and pyroxene outstand within a very fine matrix.

The Jordão River Basin, as all of the other areas having a volcanic flow covering is cut by tectonic lineaments corresponding to the most intense subvertical fracturing zones or consolidated faults.

3.2- Geology of the Selected Site

At the Dam Site, as shown in Figure 1, there is a basalt flow outburst called **GF** and identified in the region by a thickness above average and also because it can be divided into two zones, "**G**" and "**F**". The first a massive basalt of about 70-80 m and the second, an upper Basalt Breccia of about 7-20 m.

The massive basalt body is formed by a lower basalt zone, fine grading, columnar fracturing, an intermediate zone, average grading with thin horizons of almost coarse grading and an upper zone, fine grading with micro-amygdale sections or with sparse amygdale.

The basalt Breccia is mainly of the siltic type, intraflow, formed by amygdale basalt fragments fulfilled with sedimentary material. At the site it is possible to find gray calcite Breccia, with irregular centimetric voids, fulfilled with quartz, calcite or zeolites.

The Breccia contact with the upper "**E**" flow is well defined but having a gradual and not well defined underlying basalt.

The rock mass is highly impervious, rarely presenting water leaks during permeability tests, despite the normal primary shapes of the flows and decompression fractures.

The soil protection and the weathered rock at the site varies from 10-12 m in the Breccia sections and from 1-5 m at the basalt areas.

3.3- Relevant Facts

Taking into consideration the soil excavation, the modified rock at the left abutment and the river bed dewatering it was observed that:

- Depressions at the Breccia zone, due to its most prominent alteration as regards the Basalt, causing cleaning difficulties;
- The abutment rock surface is made up of practically fresh material, recovered in certain zones by a yellowish limonitic layer;
- In the River bed, below the water fall, deep depressions were identified, caused by a wearing process of rock against rock forming gravel and round wells;

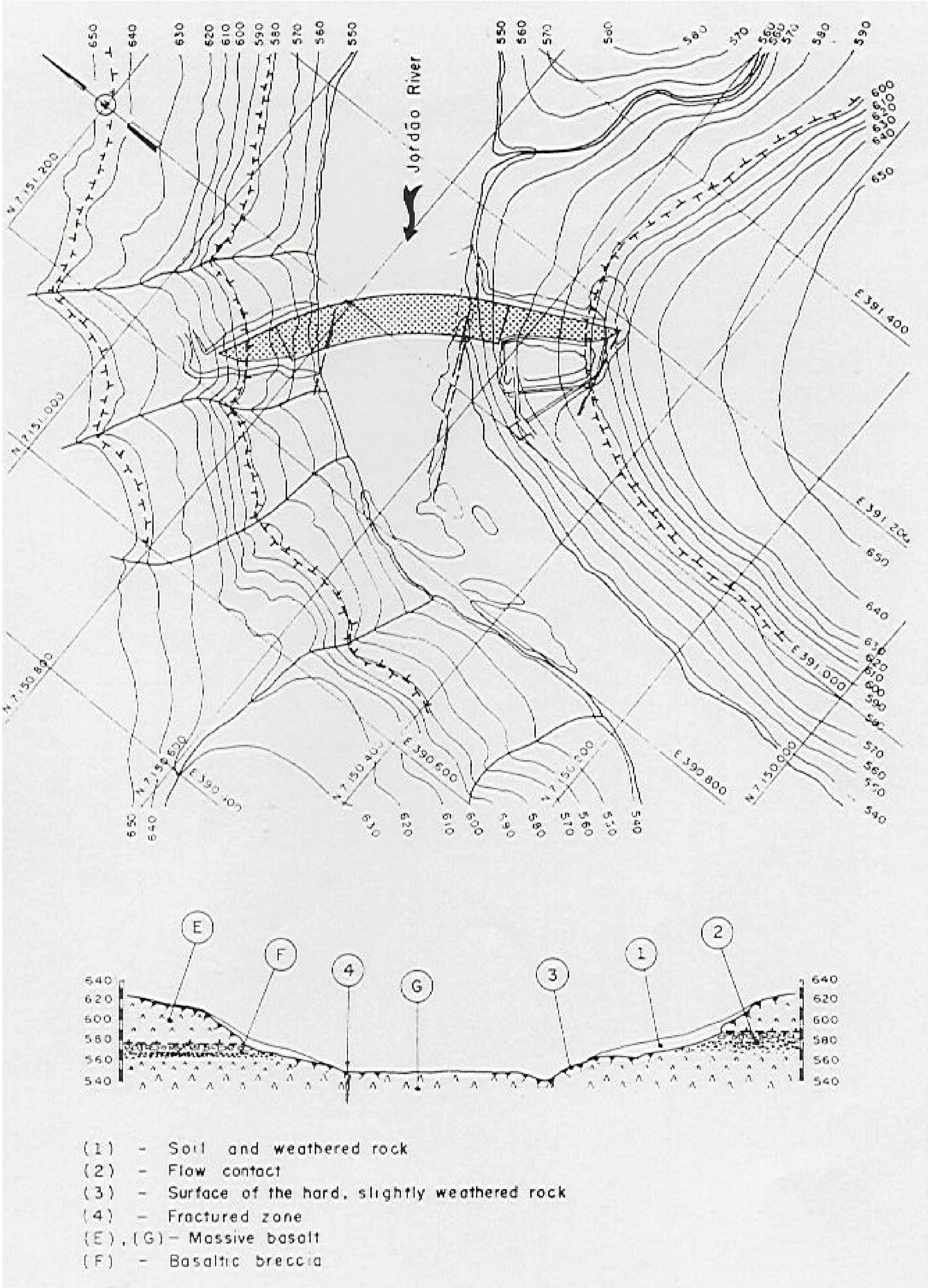

FIGURE 1 - Plan and basic geology section;

- A considerable part of the depressions found was fulfilled with gravel so the topographic-bathymetric survey and the foundation's cleaning, due to the wells size, was very difficult.

3.4- Required Treatments

According to the Technical Specifications [2], the foundation for the Dam construction shall be of fresh rock, completely clean and having no loose material or decomposed rock. To this end the following items shall be followed:

- Mechanical Specification;
- Excavation with manual levers or striking levers;
- Removal explosive-controlled.

4- FOUNDATION TREATMENTS

4.1- General

Taking into consideration the geomechanical requirements of the Project, topographical surveys were carried out within every foundation area of the dam to prepare the specific detailing. After that started the preparation [3] of the foundation for concrete pouring.

4.2- River Bed Region

This area had a very irregular surface (see Figures 2 and 3). Loose material, fragments and rock alterations were removed and afterward, water-blast (or sand- blast) clean up under pressure to remove the whole rusted material of the rock surface.

In order to meet the Project requirement that specifies a thin layer of conventional concrete to be applied in the surface contacting the rock, the surface was prepared so as to pack the existing cavities, aiming at an accessible surface to be used by the RCC application equipment.

FIGURE 2- General view of the left margin rock surface

FIGURE 3- Very Irregular surface at river bed area

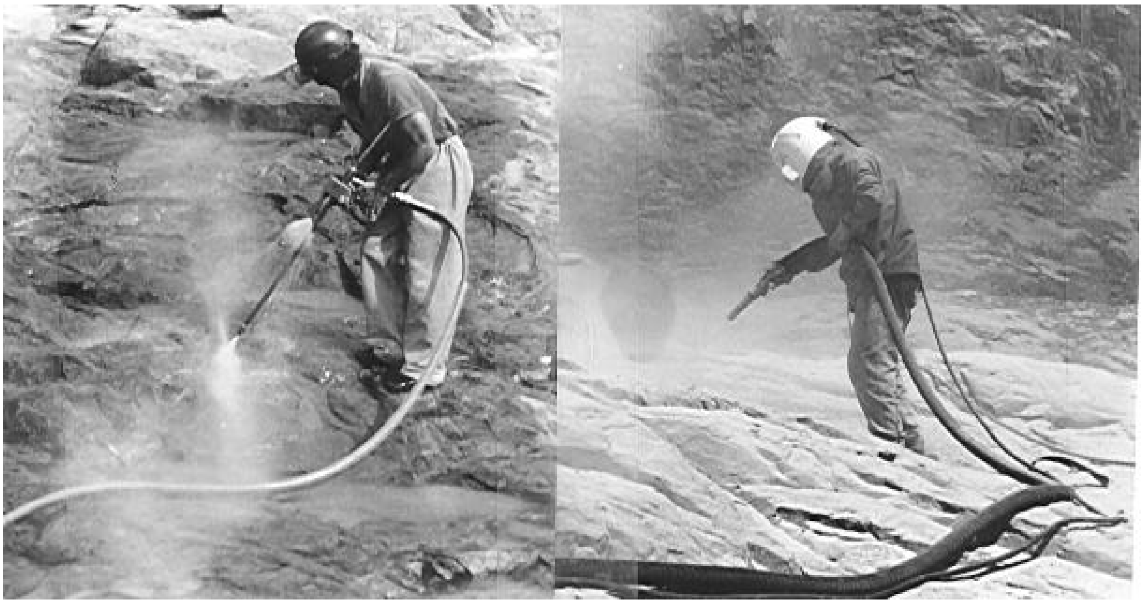

FIGURE 4- Application of high pressure water-blast (left) or sand-blast(right) to remove the limonite ore

The purpose of fillinfg the cavities was to reduce the conventional concrete that would be necessary for the total leveling of the work site, once the minimum average thickness to cover the rock was specified to be 7.5 cm. The adopted 16,0 MPa conventional concrete for this purpose has the characteristics shown in Figure 5.

MATERIAL	[illegible]	CONTENT	
		[illegible]	12MPa
• CEMENT	Kg	192	171
• CRUSHED SAND	Kg	1068	1101
• CRUSHED COARSE I (25- 4,8 mm)	Kg	550	550
• CRUSHED COARSE II (50 - 25 mm)	Kg	550	550
• WATER	Kg	149	142
• ADMIXTURE - PLASTICIZER	Kg	3,08	1,37
• ADMIXTURE - AIR ENTRAINING	Kg	0,48	0,43
PROPERTIES	**UNIT**	**VALUES**	
		16mpa	**12MPa**
• SLUMP	cm	8 +/_ 1	4 +/- 1
• AIR ENTRAINED	%	4 +/- 0,5	4 +/- 0,5
• f'c - MINIMUM REQUIRED STRENGTH / AGE	Mpa / DAYS	16,0 / 180	12,0 / 180

FIGURE 5- Conventional Concrete used to level the area contacting the rock foundation

Adopting the concept of minimizing the leveling concrete to leave only the accessible area, and not necessarily leveled, permitted to reduce the concrete consumption from 0.25 to 0,14 m^3/m^2 (contact area) as checked through tests done at river bed rock surface.

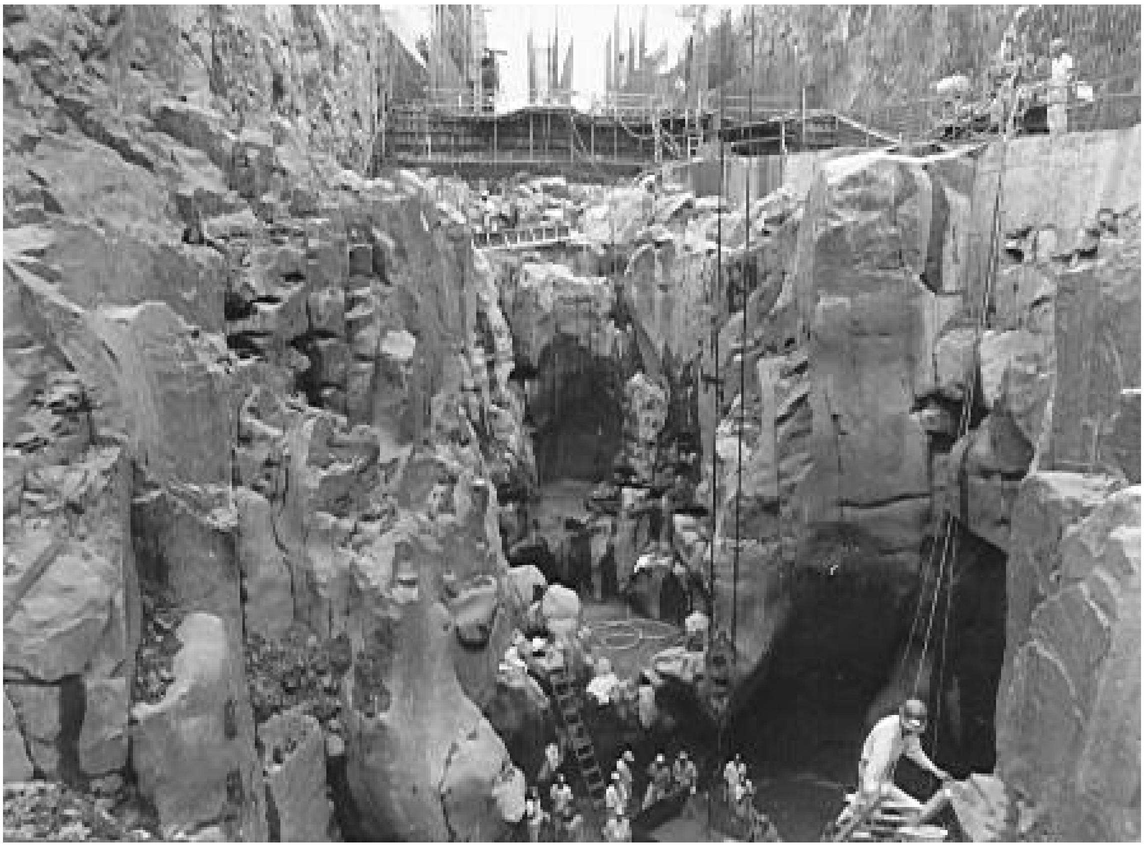

FIGURE 6- Cavities at the foundation rock right at the downstream Sluiceway

4.3- Sluiceway Region

As it may be observed in Figures 7 and 8, the cavities and wells are more evident at the region where the sluiceway was originally supposed to be implemented. Although it has been planned to dislocate approximately 25 m the Dam Axis to the upstream, it has been quite evident the interferences' occurrence, mainly downstream the sluiceway .

To remove the loose material existing in the cavities, it was used a backhoe-excavator **(**See Figure 7) and a mobile crane, complemented by an intense manual work due to the size and imperfections of the job. These were:

- Removal of blocks and loose rock fragments;
- Removal of gravel, sand and slurry;
- Pressurized water-blast cleaning of the remaining rock surface;
- Concrete placement.

FIGURE 7- General view of cavities preparation downstream the Sluiceway

FIGURE 8- Equipment used for cavities' cleaning

Foundation cleaning works at this region started in October and finished by December, 1994.

At the time, the RCC production system was not yet implemented (final adjustments and gauging were still missing) and in order to continuously execute the concreting, cyclopean concrete was applied, with the addition of stones to the 12.0 Mpa concrete in the equivalent of 8% of the volume mentioned in Figure 5, thus trying to get a reduction in the thermal gradient. The following sequence was adopted:

- Placing of conventional concrete in the entire cavity area (0.15 m layers);
- Placing of the large stones (@ 10 cm, approximately) over the concrete layer just placed;
- Placing of the subsequent conventional concrete layer.

Pneumatic vibrators with 90 mm diameter were used for consolidation; re-vibration of the contact perimeter with the surface of the cavity wall.

Taking into consideration the difficulties for execution and the volume of concrete involved, the works had to be submitted to a revision of the sluiceway's construction planning in order to keep with the scheduled frames that were feasible, also due to the anticipation of the cofferdam and dewatering works and starting of the rock excavations. 7.000 m^3 of concrete were applied to these fillings.

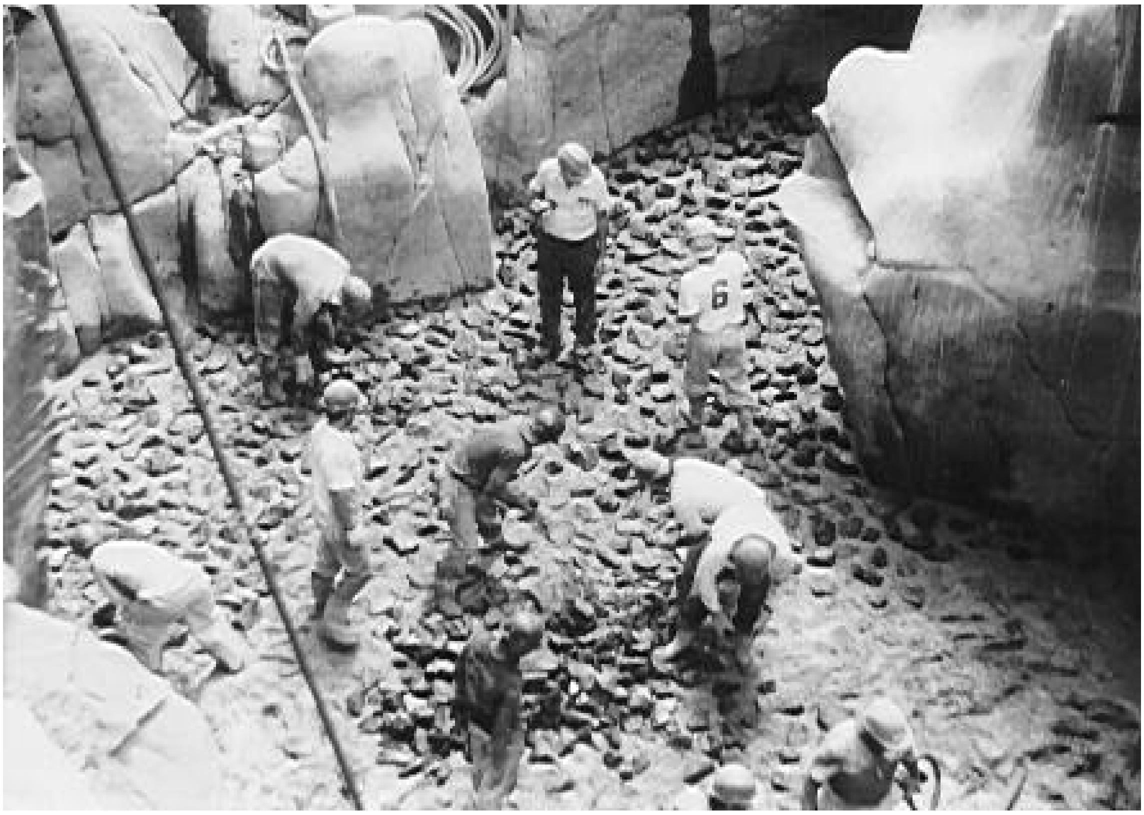

FIGURA 9- Condition observed during the filling of the cavities near the Sluiceway

4.4- Abutment Region

At the Left Abutment the back- filling concrete to the shallow cavities that were revealed after the soil excavation in the scoured area, was carried out up to levels that enabled the equipment transit for the RCC execution. The cavities were filled with 12.0 Mpa concrete (Figure 5) according to a chronological plan compatible with the RCC execution sequence.

The preparation of this region was executed as already mentioned in item 4.2. Sand-blast was adopted instead of water-blast to remove the limonite layer existing on the basalt surface. The following productivity parameters were observed during these operations:

- **Team Production = 3,29 m^2/h**
- **Sand Consumption = 0,02 m^3/m^2**
- **Workman Labor = 0,46 Hh/m^2**

To evaluate the performance of this type of treatment samples were extracted from a trial block concreted for tensile and shear tests.

FIGURE 10 - View of the irregularities observed at the left abutment

It is to be mentioned that the type of surface preparation adopted do not retard the sequence of the RCC execution works; it is only necessary to take such activity into consideration in the works' planning.

The criteria adopted to define the conventional concrete thickness next to the foundation rock was based on the surface slope, as follows:

- Slope greater than 15° - average thickness up to 7.5 cm;
- Slope equal to or less than 15° - thickness of approximately 30 cm;
- The rock surface is kept under the Saturated Dry Surface, up to the concrete placing.

FIGURE 11- Aerial View of Dam construcion by April/1995

5- COMMENTS

5.1- The positioning of the structure in relation to the natural barriers at the development site must be the guideline to be used in the Projects and not necessarily will act favorably for the progress of the works.

5.2- Geological characteristics at the dam site are exceptionally good forming a hard rock surface and practically fresh. However, facts concerning the Breccia alteration in defined spots and the rock wearing due to the water action, directed to other work cleaning and foundation treatment.

5.3- It is important to mention the need for topographic and geological studies in analogy to those developed by COPEL so as to reduce the effects of eventual alterations in the Foundation of a Dam, as regards time frames and costs defined in the development. This is clearly more convenient when it is noticed the predisposition of adopting Joint-Venture, Concessions or Turn Key concepts for new contracts.

5.4- It was observed in the Dam Implementation site during the project studies and it was confirmed during the foundation grouting works the complete imperviousness of the rock embankment with not one water leakage during permeability tests. This fact results from the local geological condition where a very thick flow is present with only one area of contact. Tectonic placements formed by small faults and fractures occur locally but closed and practically impermeable.

6-REFERENCES

[1]- Blinder, S.; Toniatti, N., B.; Krempel, A., F.- “RCC x CFRC Dams - Costs Comparison” - International Symposium on Roller Compacted Concrete Dams - Santander- Spain- October-1995.

[2]- “Technical Specifications - Segredo Power Plant - Jordão River Derivation“- Bid Document.

[3]- “Procedure to execute the Recomposition concrete of the foundation rock in the Galleries Region" - Ivai-Del Favero Consortium - 1994