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Causes of Filtration the Water in Roller Compacted Concrete Dams (RCC). 2° Part – Recommendations

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Abstract- **This work is a continuation of the one published at 8th International Conference on Advances in Civil, Structural and Mechanical Engineering – ACSM 2018 – Paris, and the International Journal of Civil and Structural Engineering – IJCSE. The origin of water leaks, construction defects and deterioration of concrete processes that, over time, would affect the safety of the dam, is explained so it is strongly recommended its intervention to stop the flow of water.**

This paper presents an ordered set of tasks that are intended to reduce water leaks and interrupt the progressive processes of deterioration on the concrete. The tasks involve treatments on the Foundation and the body of the dam.

To avoid water leaks of the dam body, a sequence of tasks is proposed to achieve the impermeability of the cracked wall.

In order to evaluate the efficiency of each one of the tasks to be carried out, it is proposed that all works are executed with water-filled reservoir.

Otherwise, with empty reservoir, there would be no way to control or to know whether the operation was satisfactory done until reservoir is refilled.

Keywords – Concrete Roller Compacted (RCC) * Dams *.

I. Introduction

The following procedure describes an intervention of the dam, in order to achieve the reduction of water leaks and stop existing progressive deterioration processes. Would they remain in time could seriously affect the safety of the dam. Intervention process is divided into two stages.

Research is the first step and aims to study the dam in detail, design injection materials, adjust operating parameters and more precisely quantify volumes of intervention in the work.

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They are tasks of conditioning deteriorated auscultation system, scanning and adjusting parameters and procedures of injection in concrete and rock.

The second executive stage, aims to recover impermeability. Intervention includes Foundation, body dam, water-stop joints and cracked walls upstream

Work will be done with full reservoir so that to each task applies the principle of "measurement - intervention - control", to evaluate the efficiency of the applied treatment in a continuous and systematic way

II. First stage. Study and analysis of alternatives.

It consists of three main tasks: Conditioning, Research and Inspection. The following diagram summarizes the content of each one of them:

FIRST STAGE		
CONDITIONING TASKS	Auscultation System Recovery	Calibration of existing instruments
		Damaged instrument replacement
		Installation of missing instruments
		Conditioning departures from foundation drains
	Location of Board Drains	
	REPORT	
RECOGNITION TASKS	Dam exploration campaign.	Perforation Execution
		Drilling logging
		In-situ permeability tests
		Tests on concrete witnesses
	Adjustment of design parameters.	Injection of two joint drains with cement and resin
		Injections in the body of the dam with cement
		Horizontal joint injections with high viscosity epoxy resin
TECHNICAL WORK INSPECTION	Control of work tasks	
	Analysis of results, conclusions and recommendations	
	Adjustment of Technical Specifications, Computation and Evaluation for the Second Intervention Phase	

Figure 1. A summary of the tasks corresponding to the first stage is shown.

A. *Conditioning Tasks.*

It refers to the auscultation system recovery, resumption recording and data analysis, as evaluation means of intervention efficiency.

Auscultation system recovery. Monitoring system is a tool of great value to identify, early diagnose and prevent the action of any process that might lead to an insecurity situation of the dam. In this case, necessary repairs and commissioning need to be done for correct operation. It is very important in this case to assess the efficiency of intervention tasks.

A frequently measurement program before and after intervention should be implemented mainly to control movements and deformations (Microgeodesia, pendulums and Rod extensometers together extensometers. Flow, temperature and pressure Control.

B. *Research Tasks.*

Exploration. In order to quantify the type and volume of injection and other intervention tasks to be performed in the Second Stage, it is proposed to perform a detailed survey of each module and its meetings. In this initial stage it is proposed to execute a series of perforations in each module of the zone to be intervened. This is intended to:

- Identify defective water-stop joints, source of water ingress, sectors and / or permeable layers.
- Register leaks.
- Analyze and map the perforations at full height from direct observation with video camera.
- Perform water permeability and / or penetration tests.
- Physically and mechanically characterize the concrete in the body of the dam through the extraction of witnesses and laboratory tests.

It is recommended to carry out at least the exploration perforations indicated in Figure 2. For each perforation a video camera recording will be made in all its height, which allows to determine the existence and position of cavities, defective construction joints, cracks that cross the drilling, water tests to determine its runoff through preferential routes, areas of HCR with manifest humidity and / or any other anomaly. In addition, in-situ permeability tests should be performed.

The "Witness Perforations" must remain open until the end of the Second Stage. They will be control points in the evaluation of the intervention efficiency and / or for the adjustment of the injections to be executed such as:

• Control of the water-stop joint repairing.

• Adjustment and control of injections intended to restore the impermeability of the upstream wall. They may be used to perform experimental injections.

• Control the efficiency of the injection aimed at restoring the impermeability of the wall. In particular, the vertical perforation arranged close to the axis of the galleries will remain open, allowing the progressive decrease of the leaks in the body of the dam to be checked and after stabilization they will be used for frequent control.

Study and Design of materials for injection. In order to determine reliable working methodologies for the execution of the injections in the dam and to be able to correctly quantify the efficiency and the cost of alternatives, test injections with cement grout and with high viscosity epoxy resins will be carried out in a module of test. This is intended to develop methodological and material aspects to be used, verify the penetration and stability of the cement slurry and / or the resin, the sealing of the discontinuities and their adhesion to the RCC.

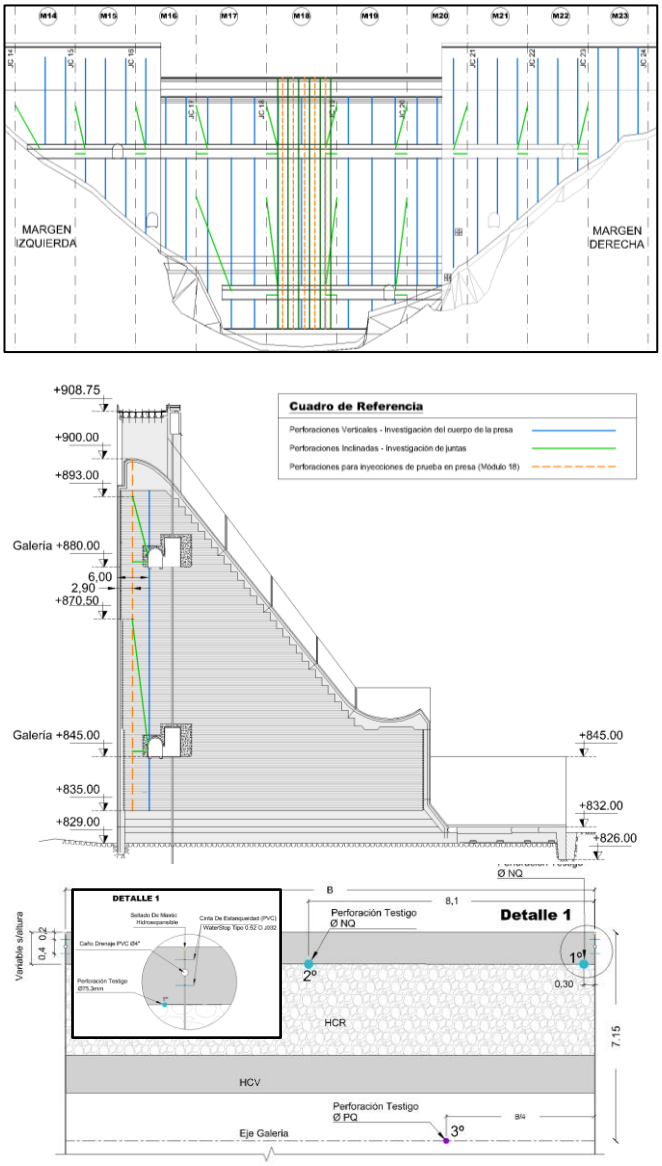

Figure 2. Exploration campaign - Distribution scheme of witness drilling (sight and cut).

Test injections will be performed on a Test Module (MP) and will consist of:

Injection of two joint drains. One drain will be injected using cement and another drain with high viscosity resin. The purpose of the alternative is to verify the stability and efficiency of the cement injection and if it is not satisfactory to have the volume and efficiency record of the injection with high viscosity resin.

In these injections, its penetration and the sealing of the discontinuities in the WS environment can be verified, using the "Control drilling" as a control tool.

Once the injection operation of the test drains is concluded, it will be obstructed by the effect of the procedure executed, so they must be periodically controlled with the "witness drilling" located next to the intervened joints using a television camera.

Injections in the body of the dam. First, test injections with cement will be executed as shown in Figure 2. If it is inefficient, test injections with high viscosity resins of defective horizontal joints would be executed. This will

work with perforations from the galleries to intercept the joints to tartar. In this way you can evaluate the materials and determine their efficiency and volume consumed in the operation.

C. *Technical Inspection (TI)*

Control of work tasks. It is advisable to track and record detailed tasks and data obtained.

Analysis of results, conclusions and recommendations. The TI must carry out the study and analysis of the data obtained in the "First Stage". Determine the operating parameters and procedures, the yields, the characteristics of the materials and their handling, the properties of the materials produced on site and the pre-elaborated ones and procedures necessary for the elaboration of the Executive Project to be executed in a "Second Stage".

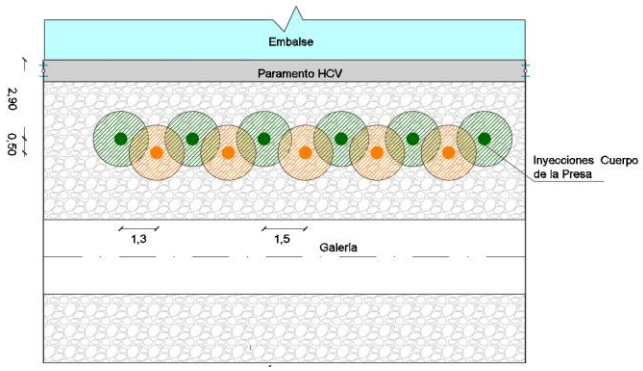

Figure 3. An injection alternative is shown in the Test Module.

III. Second Stage. Executive.

Upon completion of the First Stage, the necessary information will be available to complete and adjust the Detail Project and proceed to its execution.

Figure 4 summarizes the tasks to be executed.

SECOND STAGE	
Foundation waterproofing curtain recovery	Inyecciones de impermeabilización en la roca de fundación
	RCC-CCV contact injections in contact with the foundation and stirrups
Recovery of the upstream wall as a waterproof screen	Sealing leaks in waterstop joints. Joint drain injection
	Sealing the leaks in horizontal joints with epoxy resin
	Injections in the Dam Body
	Execution of board drains
TECHNICAL INSPECTION OF THE WORK	Intervention Control
	Continuous evaluation of the intervention

Control → OK → FIN
No OK → JC injection with Epoxy Resin

Figure 4. The summary of the tasks corresponding to the Second Stage is shown.

A. *Recovery of the waterproofing curtain in the foundation.*

In the first part of this work it was commented how the waterproofing curtain was being affected by sulfate attack and that its efficiency was 50%, lower than the minimum 67% considered in the project, so its intervention was recommended. For this, it was recommended to perform waterproofing injections in the foundation rock, RCC-CCV contact injections in contact with the foundation and stirrups and also the Drainage Curtain Reconditioning

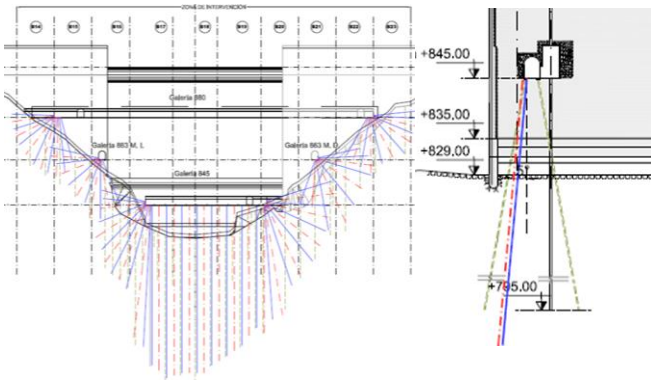

Figure 5. A proposal to recover the foundation's waterproofing curtain is shown.

A. *RECOVERY OF THE WATERPROOF FACING*

The restoration of the impermeability of the upstream facing comprises the following tasks:

Sealing leaks in water-stop joints. It applies to WS joints that show problems. The repair of joint areas is viable due to the existence of the drain arranged between the double WS. In effect, repairs must be carried out by injecting the drains located between the WS of each JC with high viscosity resin or cement as defined after the research campaign. The material adopted will be the one that meets the requirements of the injection. Control well No. 1 will be used to verify the efficiency of the intervention at each WS joint.

Sealing the leaks in horizontal joints with cement or with high viscosity epoxy resin. After the injection of the WS joints, the expected flow rate is significantly reduced. Even so, it is very likely that some leaks continue to occur through cracks in the wall and circulate through the body of prey through defective or more porous horizontal construction joints. During the exploration campaign of the First Stage, the quantity of this type of joints had to be detected and to identify by which of them leaks occur and what material is suitable for sealing, cement paste or high viscosity resins.

If necessary, the sealing of the horizontal planes detected with water flow and constituting preferential filtration paths must be executed in the first instance. This stage will be executed from the inside the galleries by means of the execution of perforations directed to the horizontal joint to be treated as close as possible to the wet wall, subsequently proceeding to the injection of cement paste or epoxy resins of high viscosity in a timely manner in the end of the drilling done.

Recovery Waterproof Screen by Injections in the Body of the Dam. This stage consists of materializing a new waterproof plane behind the current wall, injecting cement paste between the entire height of the dam and mainly in the layers of greater porosity. It will work from the crown, with vertical perforations and as close as possible to the wet face of CCV, reaching CCV in contact with the foundation.

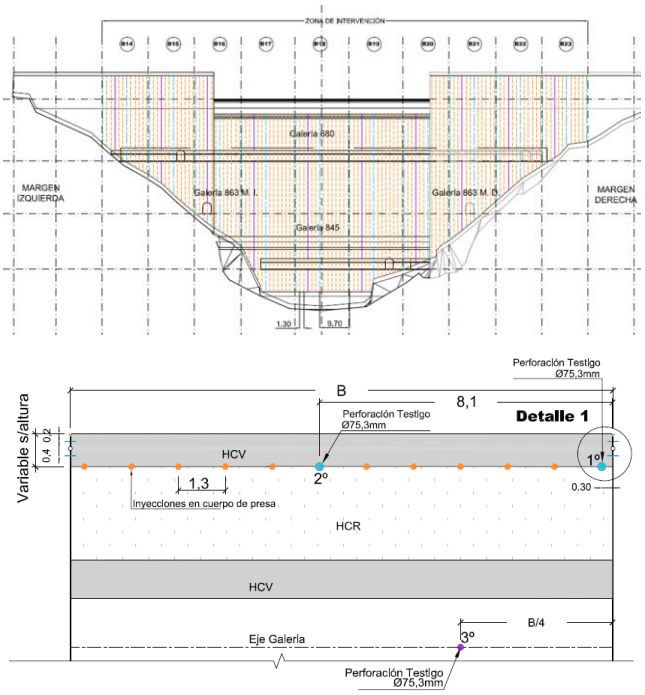

Figure 6. Scheme of distribution of horizontal joint injections with high viscosity epoxy resin.

Execution of dam drains After the completion of the injection tasks in more than two adjacent modules, the drilling of dams can be started from inside the galleries. They will be in all cases with an upward direction and will be oriented upstream to the vicinity of the intervened vertical plane.

Additionally, these drains are a tool for controlling the intervention carried out, so that the drilling of each of them must be carried out with the extraction of witnesses and inspected with a video camera along its entire length.

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