Roller Compacted Concrete Seminar 2008 Dams & Pavements

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Radisson Resort Gold Coast

RCC Dam Material and Design Philosophies

Wednesday 9th April- 2008

11.00am – 11.30am on the Low Cementitious Approach

RCC : Looking for Simplicity !

Cementitious Content: Just the Necessary!

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RCC: Looking for Simplicity! *Cementitious Content*: Just the Necessary!

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Keywords: RCC- Roller Compacted Concrete, Low and High Cementitious Content, Simplicity, Cost, Quality, Safety, Fine, Pozzolanic Material, Rock Flour, Project, Soil-Cement

ABSTRACT

There is no **SINGLE SOLUTION** for all dams! Each place, each type of available material presupposes adjustments! **Knowing how to do!**

In this publication the Author establishes the validity behind the use of "**tendencies**" for RCC Materials, taking into consideration that the availability for constructing a Dam Designt is a substantial condition in composing the Cost of the Undertaken Project.

- There is no reason for designing a Earth Fill Dam in a region where there is no soil availability! Or in a highly rainy region!
- Similarly, a Rock Fill Dam should be in a region where rock is easily altered?
- Nor should a substantial amount of Pozzolanic Material be used in a region where there is no availability of this type of material?
- What is (are) the reason(s) for requesting a greater cementitious content for RCC dams than for CVC Mass dams, with similar dimensions and constructed in similar seismic scenario?

Independently of the type of solution feasible for a Dam Design, it is highly recommended that the Project's safety proposals be preserved in order to maintain the Quality and Durability of the Project.

The aspects of Construction Joint Treatment, of the Face System, and of the Drainage System should be discussed and the Design's Safety established for each type of RCC Dam and then related to its functionality (flood control, supplying, irrigation, hydroelectric, and/or multiple uses) as well as the Operation and Maintenance aspects.

The Dam, as any other Project, is **Commonweal Public Property**, vitally important and is above and beyond any Trademark, Philosophy or Semantic Vanity!

There should be no leeway for **Regret**! In other words, to bypass conditions that may randomly reduce Quality and Durability.

What is (are) the reason(s) for requesting a greater cementitious content for RCC dams than for CVC mass dams, with similar dimensions and constructed in similar seismic scenario?

INTRODUCTION

This Author introduced the RCC in Brazil in mid-1976, through application of this material as the basis for the floor of the Contractor's Warehouse, at the Job site of the Itaipu Hydroelectric (Brazil/Paraguay).

Today Brazil has about 60 RCC Dams and many RCC pavement area. Since that time there have been many situations for learning, errors and successes. Also, there have been many laboratory studies, experimental applications and participations in Design and Constructions. Some of them are commented in this text, but all of these can be discussed with the participants of this seminar!

Included in the successes we can cite the pragmatism in the Search for **Simplicity**!

- Simplicity in the Search for Materials to use in the RCC;
- Simplicity in the Design Conception;
- Simplicity in the Lay Out and Construction facilities;
- Simplicity in the Control

All of this with adequate **Dynamics** that is compatible with the **Methodology.**

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Floor of the Contractor's Warehouse in Itaipu-1976 | **First Experimental Fill in Itaipu - 1977** | **Back filling in Itaipu- 1978**

Figure 01- First RCC applications in Brazil in 1976

The Invitation made by the Organizers of this Seminar quoted (in December 2007) the following premises for this meeting (transcript of the e-mail):

*"….Across the market there are a large number of engineers and construction companies who are interested in utilizing RCC and tendering for RCC project with little familiarity of the construction method. We are increasingly approached by contractors to make presentations on a broader range of RCC issues which as best consolidated into a **training seminar**…."*

In the Theme of **RCC Dam Material and Design Philosophies-** the Author will talk about and present ***"Low Cementitious Content".***

The Author, initially, reports not being happy about talking about **Dogmas** and neither of **Trademarks**, given that it does not reflect the correct sense of Engineering. But he does agree to discuss the theme, precisely for the didactic purpose of clarifying the reasons for using one or another material.

- ☹ What is Low Cement or Cementitious Content- or High Cementitious Content?
- ☹ What limit should be considered?
- ☹ What is (are) the reason(s) for requesting a greater cementitious content for RCC dams than for CVC mass dams, with similar dimensions and constructed in similar seismic scenario?
- ☹ Or is it merely semantics by some professionals who sit behind a desk looking for definitions?

Previously a "Trade Mark" was attempted by naming it "**High Paste**", after it was seen that virtually all RCCs were in fact "**High Paste**", because the Filler in the Fine Aggregate [01 a 05] used should also be considered in the "Calculations", hence justifying the name, some professionals sought to change the name for **Low** and **High Cementitious** or **Cement Content**.

At this moment a **New Trade** is trying to be set, as:

"….Design philosophy

The majority of RCC dams are now constructed containing a cementitious content of 150 kg/m3 or more and contain a significant proportion of a pozzolan, as .are practically all the RCC dams in…. This is clearly shown in … that shows the proportions of RCC dams that are:

- *Hard-fill dams (i.e. low cementitious RCC dam with symmetrical sloping upstream and downstream faces;*
- *Lean RCC dams with a cementitious content of 99 kg/m3 or less;*
- *RCD (rolled-concrete dam) from Japan;*
- *Medium-paste RCC dams with a cementitious content between 100 and 149 kg/m3*
- *High-paste content RCC dams with a cementitious content of 150 kg/m3 or more…."*

The CONCRETE does not know the name it is called! Some "professionals" seek such unnecessary definitions.

CONCRETE is characterized by **PROPERTIES**! And ensues in the need to specify properties and technical requirements.

One of the premises of Engineering is: **Do the best**

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Andriolo, Francisco Rodrigues

with what there is! That is, minimize the import from one location to another, of materials; reduce transport, pollution and environmental damage. Try using the minimum amount of more costly and difficult material, giving priority to the less noble materials, but without leaving behind Security, Quality and Durability.

In other words: **Simplicity, Rapid, Less Cost, Safety, Quality and Durability**, are and should be the principles!

It is very important to mention the conclusion set by Forbes and Bouygue [*High RCC Dam with Low Grade Aggregates - Bernard Bouyge; Brian A Forbes (France)*- Proceedings of the *New Progress on Roller Compacted Concrete Dams- The 5th International Symposium on Roller Compacted Concrete Dams- November/2007-Beijing-China*] as a looking for Simplicity, Low Cost and keeping the Safety, Quality and Durability levels:

> *"…5 Conclusions*
>
> *(1) **Use of weak alluvial aggregates was necessary in the absence of other economical materials**. With a significant washing and screening process, minimum period of stockpiling and careful transportation to minimize further breakage, the aggregates have been able to be used in a RCC mix which has been designed with a high workability and reduced coarse aggregate quantity to limit further breakage during the placing process. Acceptable strengths are being achieved with a low Coefficient of Variation although the sample strengths are 35% higher than the required core strengths…"*

.

PRECEDENTS AND POSSIBLE ELUCIDATIONS

For reasons of Logistics and Costs, in the first 11 years of professional life, the Author was involved in more than 20 million m³ of concrete, basically Conventional Mass Concrete, in which the search for reducing costs, with the minimization of cementitious, and intensification of local material was incessantly pursued.




Ilha Solteira ydroelectric- 3,600,000m³- Mass Concrete	Itaipu Hydroelectric- 13,200,000m³- Mass Concrete	Tucuruí Hydroelectric 6,000,000m³- Mass Concrete	Porto Primavera Hydroelectric- 1,800,000m³- Mass Concrete

Figures 02- Some Dams in the Brazilian Hydro Scheme- Constructed between 1968 and 1985, in which the cementitious content was between 80 and 120kg/m³

In the concretes of the Hydroelectrics of **Itaipu**, **Agua Vermelha**, **Ilha Solteira**, **Capivara**, and **Porto Primavera**, the average Cementitious Content (Cement + Pozzolanic Material) for **all** the concretes (**Mass and Reinforced**) was less than 170 kg/m³. It should be noted that Brazil is a non-seismic (or very low seismic) region.

The massive concrete considers compressive strength at ages 180 and 365 days (between 1968 and 1985), with contents of up to of 61 kg/m³ of Cement and 23 kg/m³ of Calcinated Clay Pozzolan, with an average strength[06] of 177 kgf/cm² at the age of 180 days, with a Coefficient of Variation of 16.9%, for a whole of more than 150 samples.

This challenge did not come about randomly, but rather the result of research studies, knowing the materials in detail.

Additionally there was the search for simpler technology and methodology, which sought to reduce operations (Production of Aggregates, Production of Concrete, Reduction of Cooling, and of the Handling

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Systems of Concrete).

And it was this reason for precisely seeking a simpler methodology - the RCC-was relevant.

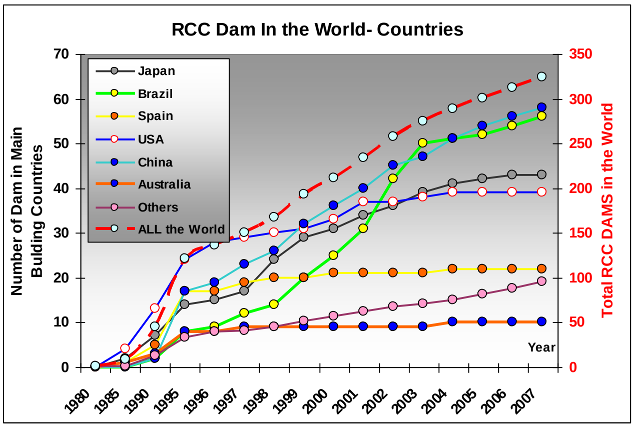
STATISTICS (?!)

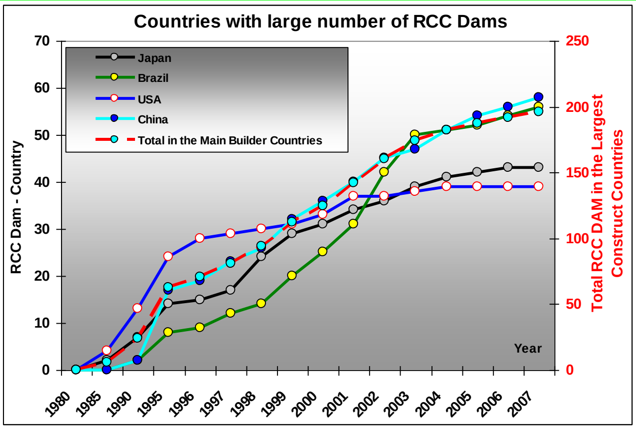
The presentation of statistical data requires interpretation and not manipulation. The justification for one type of use does not establish credit simply from endorsement by the majority, but it can be evaluated, understanding the reasons why the majority accepted them.

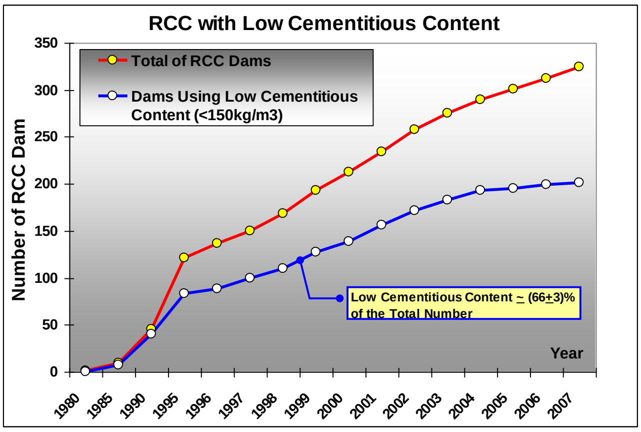
The set of RCC Dams Worldwide was over 330[07] by the end of 2007 and may be currently 350, given that various entities from several countries avoid sending information, in order to reduce the harassment of professionals regarding the decisions of the Projects.

For purposes of this presentation, and only with the purpose of clarifying the less informed, the limit between Low and High will be established with a value of 150 kg/m^3 of Cementitious (cement + Pozzolanic Material) or of 110 kg/m^3 cement! There may be disagreement, but the Author tries to demonstrate that this is not what is most Important! Understanding yes!

From this set the following interpretations can be established:







Figures 03- Information about the RCC Dams in the World, in the Countries with the highest number of RCC Dams and aspects of the use of Cementitious Content.

- ☹ **Would it be valid to say that the majority (more than 65%) of RCC Dams in the world, used and continue using Low Cementitious Content (and this is maintained) without understanding the reason for such preference?**

Of course not!

- ☹ Nor is it Logical, and less Rational, that a Trademark should be sought (this issue has already been discussed and published in other Symposiums and Conferences) [02 to 05]
- ☹ Nor is it logical to establish Technical Specifications, without knowing in detail the country, the region or the very Idiosyncrasies where the Work takes place;
- ☹ And even less allege: ***Oh! This dam is Special! It has to meet Special Parameters!***

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It is convenient looking for **Simplicity, Rapid, Less Cost, Security, Quality and Durability**.

Or otherwise the Construction Industry of Concrete Dams will gradually lose more ground to Dams of Earth and Rock Fill Materials!

USE

The use of Low Cementitious content is not a new habit, because it comes from a quite a long time ago in CVC-Mass Dams, and from the first RCC Dams, with the results shown below.

CVC Mass Dams

Cited from ACI – 207 (American Concrete Institute)[08]

> *"… Cement content—During the late 1920s and the early 1930s, it was practically an unwritten law that no mass concrete for large dams should contain less than 223 kg/m³ of cement. Some of the authorities of that period were of the opinion that the cement factor should never be less than 335 kg/m³. …. The degree of cracking was objectionably great.*
>
> *For Hiwassee Dam, completed by TVA in 1940, the 223 kg/m³ cement-content barrier was broken. For that structure the cement content of the mass concrete was only 167 kg/m³, an unusually low value for that time. Hiwassee Dam was singularly free from thermal cracks, and there began a trend toward reducing the cement content which is still continuing. Since this time, the Type II cement content of the interior mass concrete has been on the order of 140 kg/m³ and even as low as 126 kg/m³. An example of a large gravity dam for which the Type II cement content for mass concrete was 140 kg/m³ is Pine Flat Dam in California, completed by the Corps of Engineers in 1954. In high dams of the arch type where stresses are moderately high, the cement content of the mass mix is usually in the range of 180 to 270 kg/m³, the higher cement content being used in the thinner and more highly stressed dams of this type. Examples of cementitious contents (including pozzolan) for more recent dams are….."* (including other Dams were the Author participated):

Project	Reference	Finished	Country	Dam Type	Concrete Volume (m³)	Concrete Type	MSA	Mix Proportion Kg/m³				Average Strength (kgf/cm²)							
							mm	Cementitious	Pozolanic Material	Total	Water	7 days	28 days	90 days	180 days	1 year	2 years	5 years	12 years
Ilha Solteira	[06 and 09]	1974	Brazil	Straight Gravity	3.600.000	Massa	152	61	23	84	85	66	134	163	177	186			
Itaipu	[09]	1982	Brazil / Paraguay	Hollow Gravity	13.200.000		152	108	13	121	85	72	142	176	180	192	206	219	
								78	9	87	85	45	79	113	120	129	136	155	
Tucuruí	[09]	1985	Brasil	Straight	6.000.000		76	94	28	122	90	75	113	140	151				
							152	73	22	95	84	63	93	121	130				
Huites	Author	1995	México	Gravity	2.850.000		76		150	150	100	90	147	173	194				
Glen Canyon		1963	USA	Arch			152	111	53	164	83		176	263	272				
Flaming Gorge		1962					152	111	56	167	88		203	241	267	323			
Yelowtaill	[08]	1965		Gravity			152	117	50	167	82			316	374	389			
Lower Granite		1973		Straight			152	86	29	115	82		88	143	167	188			
Libby		1972					152	88	29	117	79		100	170		220			
Dworshak		1972		Gravity		CVC	152	125	43	168	97		83	140		214			

Figure 04- Conventional Vibrated Concrete Dams – CVC Mass Concrete

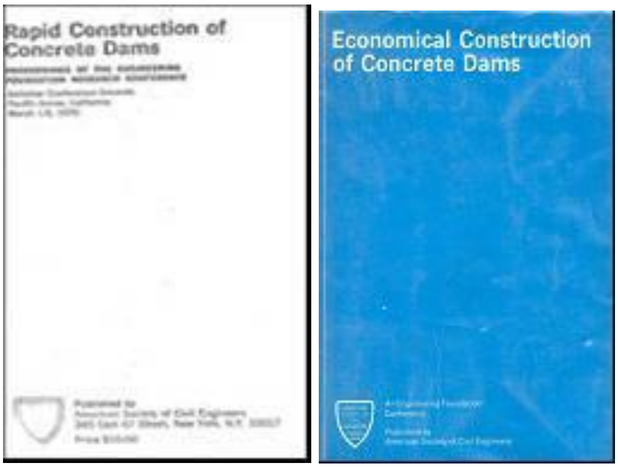
☹ What is (are) the reason(s) for requesting a greater cementitious content for RCC dams than for CVC mass dams, with similar dimensions and constructed in similar seismic scenario?

RCC Dams

Since the first RCC Dams, there was a preference for using **Low Cementitious Content**, as described below, with evident costs reduction.

The origin of RCC Dams, taken as a reference from the Asilomar Conferences in California, can be conveniently remembered:

- ☞ in March 1970 - Rapid Construction of Concrete Dams - ***"The optimum Gravity Dam"*** - Prof. Jerome Raphael[10];
- ☞ in May 1972- Economical Construction of Concrete Dams[11] and respective discussions, should be recalled:



[10] *"....The very lean concrete dam such as Professor Raphael apparently has in mind, would require that the upstream face have an impervious membrane which could be cemented.. provide to prevent deterioration from weathering…"*

[11] *"... it should suffice to say that the construction procedure is feasible, and that concrete compacted by this procedure is in every respect equal to or higher in strength than conventional concrete with equal cement content…* (This paper would be advised for all professionals that are under a training seminar!)

[12] *"…It is conclude that the techniques are here to take the next step to building the economical soil-cement dam…."*

From these assertions the practice of Low

Cementitious Content was adopted at the outset of the first RCC Dams in the United States.

Almost simultaneously [13,14,15], Japan started the assessments for using the RCC in 1974, adopting the nomenclature RCD, with agglomerate content of 130 kg/m^3 (with 91 kg/ m^3 of cement and 39 kg/m^3 of Fly Ash). But the professionals of Semantics explain that is not **RCC** but instead it is **RCD**!

China, another country that is a great builder, began studies for the implementation of the RCC around 1980, with cementitious content of 120 kg/m^3 to 152 kg/m^3, and the dam of Kengkou effectively began the cycle of RCC substantial works in China, with a consumption of 140 kg/m^3 of cementitious contente (60 kg/m^3 of cement and 80 kg/m^3 of Fly Ash)[16].

From this set of Dams it is relevant to mention the ones that showed more strength at later ages, as those illustrated below.

The average Splitting Tensile Strength/Compressive Strength relationship (indirectly by diametrical compression) was around 11%, and the Direct Tensile/Compressive Strength was between 6% to 7%.

Obviously, when a particular property is requested then the dosage should be sought, with the available materials to meet this property. For example, greater resistance for the RCC of a Double Curvature Arc Dam, or for the Pavement. But such concrete dosed like this, and applied by compaction with a Vibratory Roller are RCC, this is - **CONCRETE**!

Project	Reference	Finished	Country	Dam Type	Concrete Volume (m^3)	Concrete Type	MSA mm	Mix Proportion Kg/m^3				Average Strength (kgf/cm^2)							
								Cementitious	Pozolanic Material	Total	Water	7 days	28 days	90 days	180 days	1 year	2 years	5 years	12 years
Capanda	[17]	1988-2000	Angola	Straight Gravity				70	(*)	70	135	58	78	98	104	110	120		130
								80	(*)	80	135	65	95	110	120	125	130		142
Hiyoshi	[18]	1992	Japão	Straight Gravity	674.000	RCD	152	84	36	120	86	76	159	269					
							152	77	33	110	83	69	149	250					
Salto Caxias	[19]	1995-1998	Brasil	Straight Gravity	920.000	RCC	50		(*)	0	143	36	50	82	114	132			
Miel I	[20]	2000	Colombia	Straight	1.800.000		63	150	(*)	150	133	114	148	178	195	219			
								125		125	130	96	126	156	176	183			
								100		100	125	68	94	119	133	148			
								85		85	123	61	85	105	118	130			
Al Wehdah	Author	2006	Jordan	Gravity	1.400.000		50	60	80	140	125	54	91	153	193	210			

(*)- Rock Flour use

Figure 05- Compressive RCC Strength Results for some Dams around the World

The first applications of RCC (around 1982-1984) confirmed the predictions for the need to take care of the permeability of the upstream side, as provided (Reference [10]) and the Tender Document for Willow

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Andriolo, *Francisco Rodrigues*

Creek[21] that occurred in the Willow Creek Dam[22], occurred in others, even with High Cementitious Content. Additionally, several studies have confirmed such high permeability

Figure 06 – Willow Creek RCC Dam aspect showing the upstream water level at downstream face

Figure 07- Cracks and leakage in Upper Stillwater [24,25]

From that time the quantity of Fines began to receive attention (material with size less than 0.075mm), which enabled to establish a new practice, which some now call the **Second Generation of RCC Dams**.

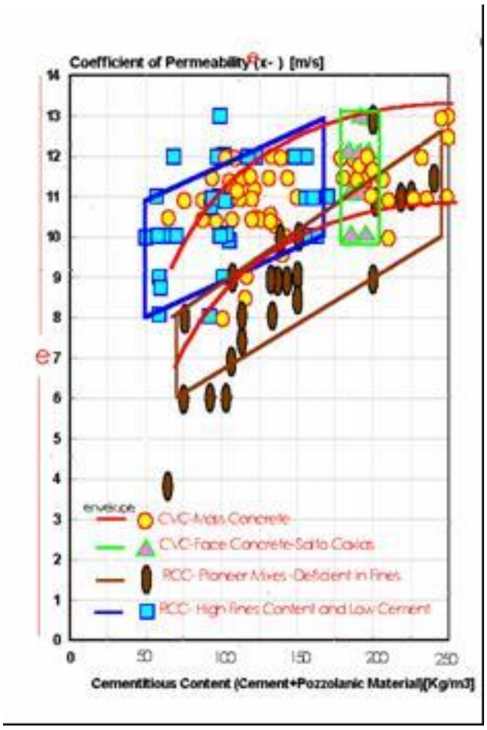

Figure 08– Permeability Results of Mass CVC and RCC. [23]

This practice shows that the reduction of permeability is not necessarily dependent on the Cement content, with permeability coefficients of 10^{-11} to 10^{-12} m/s with cementitious levels of around 100kg/m^3. **That is, the practice of using Fines (mainly Non-Cohesive; Non-Clay) was established, with obvious advantages.**

Additionally, it should be understood that the contemporary machine production of aggregates (Crushers) enable obtaining rounded sand grains, and because of this, they produce a reasonable amount of fine aggregates. That is, besides these fines being a "by-product", they have a relevant utility, **with low cost.**

Furthermore, depending on the mineralogical characteristics of the matrix rock, which is used to produce aggregate, these fines may present some "Pozzolanic Activity " increasing the resistant properties (see evolution of the resistance of RCC

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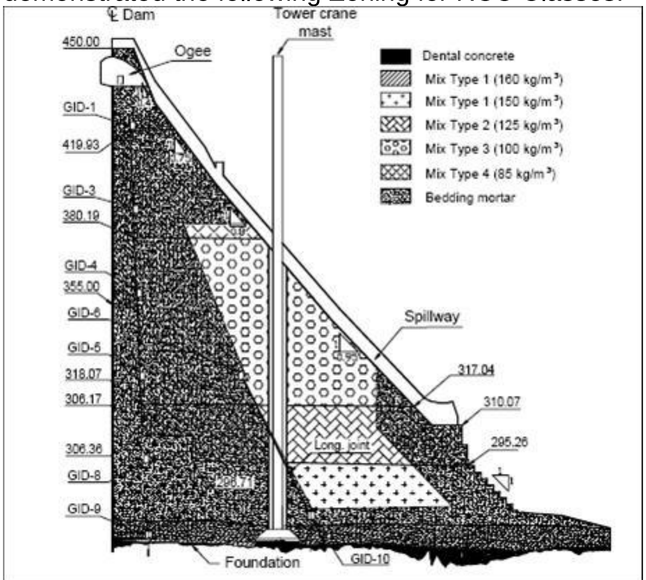
used in the Capanda Dam, where an OPC cement type was used, with the Meta- sandstone fines, and also in the, Salto Caxias and Miel I Dams).

Similarly, around 1985 the attempt to execute RCC Dams without contraction joints[24; 25], and the High Cementitious Content, induced the occurrence of a systematic overview of cracks.

Thermal studies started to get attention, as well as placement temperature control, adoption of the Contraction Joints, unlike what is preconized for Simplicity, (Note References [10] and [11]), and even the induction for using RCC Pre-Cooling.

Construction of the Miel I Dam- Colombia[20], demonstrated the following Zoning for RCC Classes:



RCC Mix	Cement Content (kg/m3)	Volume Used (m3)	% Related to the Total RCC Volume
1. A	**160**	**29.930**	**1,7%**
1	**150**	**255.480**	**14,6%**
2	**125**	**438.100**	**25,1%**
3	**100**	**709.800**	**40,7%**
4	**85**	**311.450**	**17,9%**

Figure 09- Class Zoning of RCC at the Miel Dam– Colombia [20]

All the Professional participants of the Miel-I Project considered that the highest CCR Dam, had practically its entire volume with RCC, **Low Cementitious Content**.

However, with the change of the acceptance limit of **Low and High Cementitious**, it could be considered that MIel I, is no longer **Cementitious Low Content**, but of **Medium Cementitious Content**, or even a **High Cementitious Content!**

- ***Pure Philosophy or Semantic Vanity?***

DAM DESIGN

The concepts of Stability and Stresses Analyses in the Body of the RCC Concrete Dam are those same ones that are conducted for CVC Dams.

What should have additional attention, **ARISING FROM THE METHODOLOGY? Is there an induced weakness? Which? What Defense should be established?**

- The conditions, due to a greater number of Construction Joints, are an RCC characteristic?
- But it also has its conditioning in the Mass CVC Dams !
- That is to say – **Where is the problem?**
- Is it worth to generalize or look for a remedy and a therapy for the specific symptomatology?

This is the analysis that, in view of this Author, should be established!

The concepts of the Stability Analysis of the Stress, from a Thermal Aspect, only undergoes adjustments due to the temporal variation and the induction speed of construction, and here the development of the properties, with the Age of Concrete, is very relevant. This has to be understood!

The amount of binder (cement and eventually materials with pozzolanic characteristics) results from the need to meet the required properties, from the previous studies.

Precisely for that!

- Regarding permeability: There are ways for establishing defenses, without necessarily increasing cementitious content
- As for the treatment requirements of Construction Joints, and the resulting properties: There are also ways to establish defenses.

Not to establish filling of voids, or for granulometric functions!

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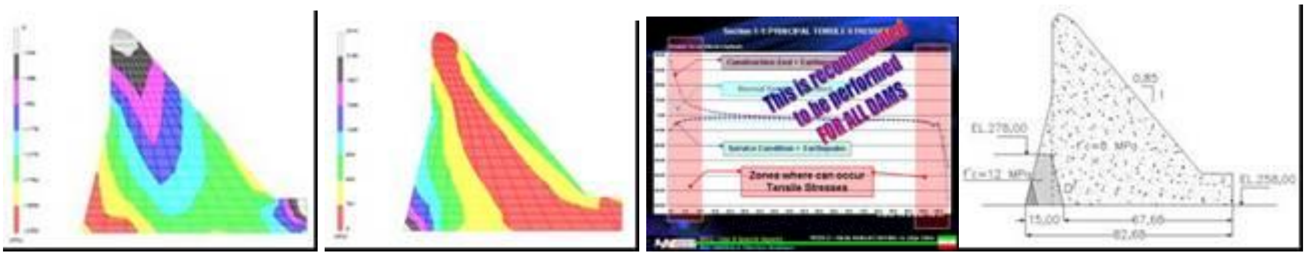

Figures 10- Diagrams of Stress of an RCC Dam Project with over 100m of height in a highly seismic region.

Moreover, one can take advantage of the Zoning of the Body of the Dam. But then, some Contractors may say:

Oh! But this will reduce Productivity!

Nonsense - this assumption cannot be generalized (see Figures 09 and 10). Clearly, it depends on how this Zoning is "Engineered"! This can be simple, with obvious costs advantages.

It is sufficient to see, even for seismic regions, that the zoning can be simple without disservice to **Speed**.

And the Thermal Aspects?

Also, another aspect that cannot and should not be generalized.

In general, the phenomenon of **"Restriction"** as well as the thermal properties of concrete and materials should be known, mastered. Knowing how they are affected. The phenomenon of **"Restriction"**, its variation with the height of the structure, with regard to the base with the Foundation (Full Restriction) should be understood by professionals who Design and specify the requirements for the Design.

The diffusion and exchange of Generated Heat (by the Hydration High or Low Cementitious!), with the Environment in the RCC is of great relevance.

Although the RCC Dams have a general concept of Massive Structure, the methodology of construction by successive layers facilitates the heat exchange more rapidly and efficiently than in a structure, also, CVC mass, with layers of 1.5m to 2.5m in height.

Then, the convenience-need to understand is:

- About variation of the phenomenon of **"Restriction"** with the concrete height on the foundation (or on a Modulus of Elasticity concrete base very different from that which is cast);
- About Diffusion-Heat Exchange with the Environment, when layers of height of around 30cm is adopted, and;
- About the Thermal Properties.

While the third item has the same importance in the massive CVC and RCC structures, the first two have a much more relevant repercussion in RCC than in traditional structures of Mass CVC.

Regarding the restriction, it is important to note that at the beginning of RCC constructions, the learning curve and the initial inertia of production, rarely lead to more than one layer of RCC per day. The Full Effective Production condition usually is reached above approximately 10% of the height of the structure. In this situation the restriction will be less than that immediately next to the Foundation and the induction of Cracks becomes smaller.

In the same situation, when applying only one daily layer of RCC, in this region, the large area and low height of the layer facilitate the (generated) heat exchange with the environment and within hours the mean temperature of the layer is similar to Ambient temperature .

If that RCC was cast at below ambient temperatures, likewise and in just a few hours the thermal balance of Layer-Environment will be seen. And in this case, it will be generating spending costs to have a Pre-Cooling, and in a few hours the balance will be noticed.

This analysis is almost general in the massive structures of gravity section, with large bases near the Foundation.

If the project is an Double Arch Structure, with smaller

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bases, there may be cases for having more than one layer of RCC per day, and then the benefits mentioned may not come about.

That is, the Construction Program idealized by the Contractor can be adjusted, bringing advantages (to the Contractor during the Tender Bidding) or the Owner, in his Budget, through the analysis of the Project with regards to technical details and concepts.

RECOMENDED VIGILANCE

The availability of materials for the construction of a Dam Project is a very important condition in formulating the cost of this Endeavor.

- There is no reason for Planning a Earth Dam, in a region where there is no soil availability! Or in a region with high rain precipitation!
- Similarly, it should be sought to have a Rock Fill Dam in a region where Rock is easily altered!
- Nor is there a reason to want to use a high quantity of Pozzolanic Material in a region where this kind of material is not found.

Regardless of the type of solution deemed viable for a Dam Project, it is highly recommended that the premises for the Project Safety be preserved in order to maintain the quality and Durability of the Project.

The aspects of the Construction Joint Treatment, of the Face System, the Drainage System should be discussed for each type of RCC Dam and related to its functionality (flood control, supply, irrigation, hydroelectric, and / or multiple uses) as well as the Operation and Maintenance aspects.

COMMENTS AND SUGGESTIONS

Each human being is unique, but he usually uses different clothes in winter and in summer, sometimes also different clothes in autumn and spring. There is no SINGLE SOLUTION for all Dams! Each place, each type of available material involves adjustments! Of Knowing How to do it!

The Dam and other Projects are Commonweal Public Properties, of extremely important utilization, which is above and beyond any Trademark, Philosophy or Semantic Vanity!

We must not give room for Regret! Meaning; give up on the conditions that can randomly reduce Quality and Durability.

- If in the nearby region of the construction there is Good Quality and Low Cost Pozzolanic Material, then use it in a quantity that is backed up by Tests;
- If there is none. Find another solution. Silte, the Stone Powder!
- If there is a need to produce aggregates (fine and coarse) do not throw away the Powder Stone. Evaluate whether the Stone Powder has some Pozzolanic characteristic. Even in small amounts, it can be used.
- If the stresses in the dam body are low; evaluate the possibility for zoning;
- If the foundation is not very good, why use high content of cementitious, and also, consider having a compatible system for watertightness;
- If the region is of high seismicity, it may be appropriate to have a less rigid face, or with dual protection, and
- This way, the project can be adjusted to local suitability.

It is important to remember that step by spet one can accomplish Professor Jerome Raphael's suggestion:

The Soil- Cement for use as resistant material for Dam Construction!

REFERENCES

[01]- Andriolo, F.R.; Gottardo, G.; Peña D.F.- *"Urugua-i: Uma Barragem em Concreto Rolado"*- Proceedings

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of the XVII Seminário Nacional de Grandes Barragens- Brasília- Brazil- August-1987;

[02]- Oberholtzer, G.L.; Lorenzo, A.; Schrader, E.- *"Roller Comacted Concrete Design for Urugua-I Dam*"- Proceedings of the Roller Compacted Concrete II- ASCE- San Diego- California- USA- March-1988;

[03]- Zanela, M.R.; Braga, J.A.; Rosário, L.C.; Ayala, A. C.; Andriolo, F.R.; Golik, M.- *"Concreto Rolado- Ensaios Especiais"*- Proceedings of the XVIII Seminário Nacional de Grandes Barragens- Foz do Iguaçu- Brazil- April-1989;

[04]- Gaekel, L.; Schrader, E.- *"RCC Mixes and Properties Using Poor Quality Materials"*- Proceedings of the Roller Compacted Concrete III- ASCE- San Diego- California- USA- February-1992;

[05]- Krempel, A.F; Andriolo, F.R.- *"High Paste Content and Low Cement Mixes, Finely Crushed Rock, Specific Gravity, Compaction Ratio, Low Cost…; Discussions and Values Obtained"*- Proceedings of the International Symposium on Roller Compacted Concrete Dams- Santander- Spain- October- 1995

[06]- Andriolo, F.R.- *"Construções de Concreto- Manual de Práticas para Controle e Execução"*- Editora Pini Ltda- Rua Anhaia 964- Bom Retiro- 01130- São Paulo- Brazil- 1984;

[07]- Year Book 2007- International Water Power & Dam Construction- United Kingdom- 2007

[08]- ACI- 207.1- *"Mass Concrete"*- American Concrete Institute- Farmington Hills, MI-USA- 1996;

[09]- *Concreto Massa no Brasil- Memória Técnica*- IBRACON- CBGB- Eletrobrás- Rio de Janeiro- Brazil- 1989

[10]- Raphael, J.M.- *"The Optimum Gravity Dam- Proceedings of the Rapid Construction Concrete Dams"*- ASCE- Asilomar- California-USA- March-1970;

[11]- Cannon, R.W.- *"Concrete Dam Construction Using Earth Compaction Methods"*- Proceedings of the Economical Construction of Concrete Dams- Asilomar- California- USA- May-1972;

[12]- Raphael, J.M.- *"Construction Method for the Soil"*- Cement Dam- Proceedings of the Economical Construction of Concrete Dams- Asilomar- California- USA- May-1972;

[13]- Shimizu, S.; Takemura, K.- *"Design and Construction of a Concrete Gravity Dam on a Weak Bedrock"*- Transactions of the XIII ICOLD Congres- New Delhi – November 1979;

[14]- Hirose, T.; Shimizu, S.; Takemura, K.- **"Studies on Construction of Dams by the RCD Method"**- Transaction of the Japan Society of Civil Engineers- Tokyo-Japan- 1980;

[15]- *Multipurpose Dams in Japan- State of the Integrated River Development Projects*- River Development Division- River Bureau- Ministry of Construction- Tokyo-Japan-May-1984;

[16]- *RCC Dams in China*- Department of Science and Technology- China Electricity Council-China;

[17]- Tavares, M.A.; Origa, M.A.; Fontoura, J.T.F.; Holanda, E.R.; Pacelli, W.A.; Andriolo, F.R.- *"* *Capanda - RCC Dam - 12 Years Quality Control Data"*- Proceedings of the IV International Symposium on Roller Compacted Concrete Dams- Madrid- Spain- November- 2003;

[18]- *Current Activities on Dams in Japan*- Japan Comission on Large Dam- Japan- 2003;

[19]- *Quality Control Data from Salto Caxias Dam*- COPEL- Parana- Brazil- 1999;

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[20]- *Control de Calidad de la Presa*- Reporte No. 16- Informe Final- Presa Miel-I- Colombia-Ingetec- July-2002;

[21]- *Willow Creek Design Memorandum*, Suplement to GDM 2- Phase 2- Main Dam, Spillway and Outlet Works- U. S. Army Enginer District- Wala Wala- Washington- USA- December-1981;

[22]- Schrader, E.- *"Beahavior of Completed RCC Dams"*- Proceedings of the Roller Compacted Concrete II- ASCE- San Diego- California- USA- March-1988

[23]- Andriolo, F.R.- *"The Use of Roller Compacted Concrete"*- Oficina de Textos- Rua Augusta 1371- Lj. 107--1305- 100- São Paulo- Brazil- 1998

[24]- McTavish , R.F.- *"Construction of Upper Stillwater Dam"*- Proceedings of the Roller Compacted Concrete II- ASCE- San Diego- California- USA- March-1988

[25]-Richardson A.T.- *"Performance if Upper Stillwater Dam"*- Proceedings of the Roller Compacted Concrete III- ASCE- San Diego- California- USA- February-1992.

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