SPECIAL WORKSHOP

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

October 18 & 19, 2007
Granada, Spain

Session 5: Remedial Actions & Prevention

Friday, October 19 8:30 a.m. – 10:30 a.m.

Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

Francisco R. *Andriolo*, Andriolo Ito Engenharia Ltda, Sao Carlos,
Marco Antonio Camargo *Juliani*, Ieme Brazil Engenharia Consultiva Ltda, Sao Paulo,
Alberto Jorge C. Tavares *Cavalcanti*, Companhia Hidro Elétrica do São Francisco, Recife,

Brazil

Part I- MATERIALS- Preventive

During the ***FIRST SYMPOSIUM ON ALKALI-AGGREGATE REACTIVITY OF CONCRETE STRUCTURE*** in Goiânia, GO, Brazil in November/1997, one of the Authors suggested that for a deeper understanding, defense and survival of concrete structures up against the RAA phenomenon, a plan is established that considers:

- ☞ Divulgation of the subject;
- ☞ Establishment of technical anthology;
- ☞ Development of *"critical mass"* of the subject;
- ☞ Inducement (beneficial) regarding dimension of phenomenon;
- ☞ Attempt at inducing research;
- ☞ Search for materials and alternative solutions to inhibit RAA;
- ☞ Search for solutions to minimize or neutralize the phenomenon, after AAR has begun.

Or we will continue to adopt the 3 methods to avoid an expansive AAR that are:

I. Use of non-reactive aggregate;
II. Limitation of alkalis proportion in cement;
III. Use of pozzolan or other additions

Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

Defensive Actions	Agent	Type	Main Actions
Defensive Actions	Chemical Admixtures	Plasticizers	Reduction in Water Content and consequently Cement Content (and a sub-sequent reduction in the Alkalies content)
		Super Plasticisers	
		Lithium Compounds	Changes in the Reactions
	Mineral Additives	Natural Pozzolans	Availability of Siliceous Materials to react in advance and faster than the reaction with the aggregates
		Calcined Clay	
		Ashes & Fumes - Natural or "By" Products	
		Blast Furnace Slags	
		Some Silt	
		Rock Flour or Rock Dust	
	Domestic "By Products"	Bottles & Glasses	Availability of Siliceous Materials to react before and faster than the
	Technical Bureaucracy	Do not use because can be dangerous !	
		Innocuous Aggregates	
		Low Alkalies Cement	

Based on this and founded in the 7 inducements suggested in the First Symposium, and also discussing, somewhat, the limitations of the 3 traditional determinations previously mentioned, it merits ascertaining the following:

☞ ***Is there no other feasible way to use Deleterious Aggregates?***
☞ ***Shall we continue to be the "Prophets of the Past" suggesting Therapies, a tradition in Countries with insignificant territorial dimensions, without acknowledging our very own conditions?***

According to the author, at times argumentative and/or provocative -

☺ ***There are other methods, and;***
☺ ***We should not condition ourselves to the problems of others!***

Based on such a proposal, this presentation encourages the search for optimization of fillers (material below 0.075mm) produced from the very reactive aggregates intending to safely use it **as a vaccine**, in order to inhibit expansive reactions.

Also, there is a need for discussion about Standard aspects and Technical Specifications for a convenient standardization, if not necessary, and knowledge application as well as safe utilization.

Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

Order	Year	City; Country	Papers	Papers Related toPreventive Actions
1	1974	Koge; Denmark	13	No one
2	1975	Reykjavik; Iceland	20	No one
3	1976	Wexham Springs; UK	27	3
4	1978	Purdue; USA	26	2
5	1981	Cape Town; South	38	11 (1 mineral additive)
6	1983	Copenhagen;	56	12
7	1986	Ottawa;Canada	101	11
8	1989	Kyoto; Japan	136	16- (Plasticizers; Superplasticizers)
9	1992	London; UK	150	22
10	1996	Melbourne; Australia	130	13 (1 about rock Flour; 1 about Admixtures)
11	2000	Quebec City; Canada	142	26 with 8 concerning anusual action (5 Lithium, 3 Others)
12	2004	Beijing; China	187	32
13	2008	Trondheim; Norway		

Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

Record	Year	Subject- Paper- Reference	Author
Journal of Geology	**1916**	Subjects Related to the Durability	E. A. STEPHENSON
American Concrete Institute	**1923**	An Interesting Case of Dangerous Aggregate	J. C. PEARSON & G. F. LOUGHLIN
Virginia Polytechnic Institute	**1935**	Concrete Expansion	R. J. HOLDEN
The Chemistry of Cement and Concrete	**1935**	Book	F. M. LEA & C. H. DESCH
Engineering News Record	**1940**	**Expansion of Concrete Through Reaction Between Cement and Aggregate,**	**THOMAS E. STANTON**
ASCE	**1941**	Discussions	ROY W. CARLSON
American Concrete Institute	**1941**	Cracking in Concrete Due to Expansive Reaction Between Aggregate and High Alkali Cement as Evidenced in Parker Dam	HARMON. S. MEISSNER
		Evidence in Washington of Deterioration of Concrete Through Reactions Between Aggregates and High Alkali Cements	BAILEY TREMPER
		The Nature of the Processes Leading to the Disintegration of Concrete, with Special Reference to Excess Alkalies	CHARLES P. BERKEY
ICOLD Congress - Stockholm	**1948**	Expansive Cracking in Concrete Dams Caused by Reactive Aggregate and High-Alkali Cement	HARMON. S. MEISSNER
ICOLD Congress- New Delhi	**1951**	Efficaite de la Pouzzolane Ajoutee aus Ciments Destines au Beton Pour Grands Barrages el Appication Recents en Italie	BIADENE & PANCINI
ICOLD Congress – Vienna	**1991**	TEMA- Ageing of Dams and Remedial Measures	Questão 65
ICAAR Conferences- Denmark	**1974**	International Conferences on Alkali Aggregate Reaction	

It is very important to remember the paper published in **1940**: *THOMAS E. STANTON-* **"Expansion of Concrete Through Reaction Between Cement and Aggregate"**-Engineering News Record, that mentions:

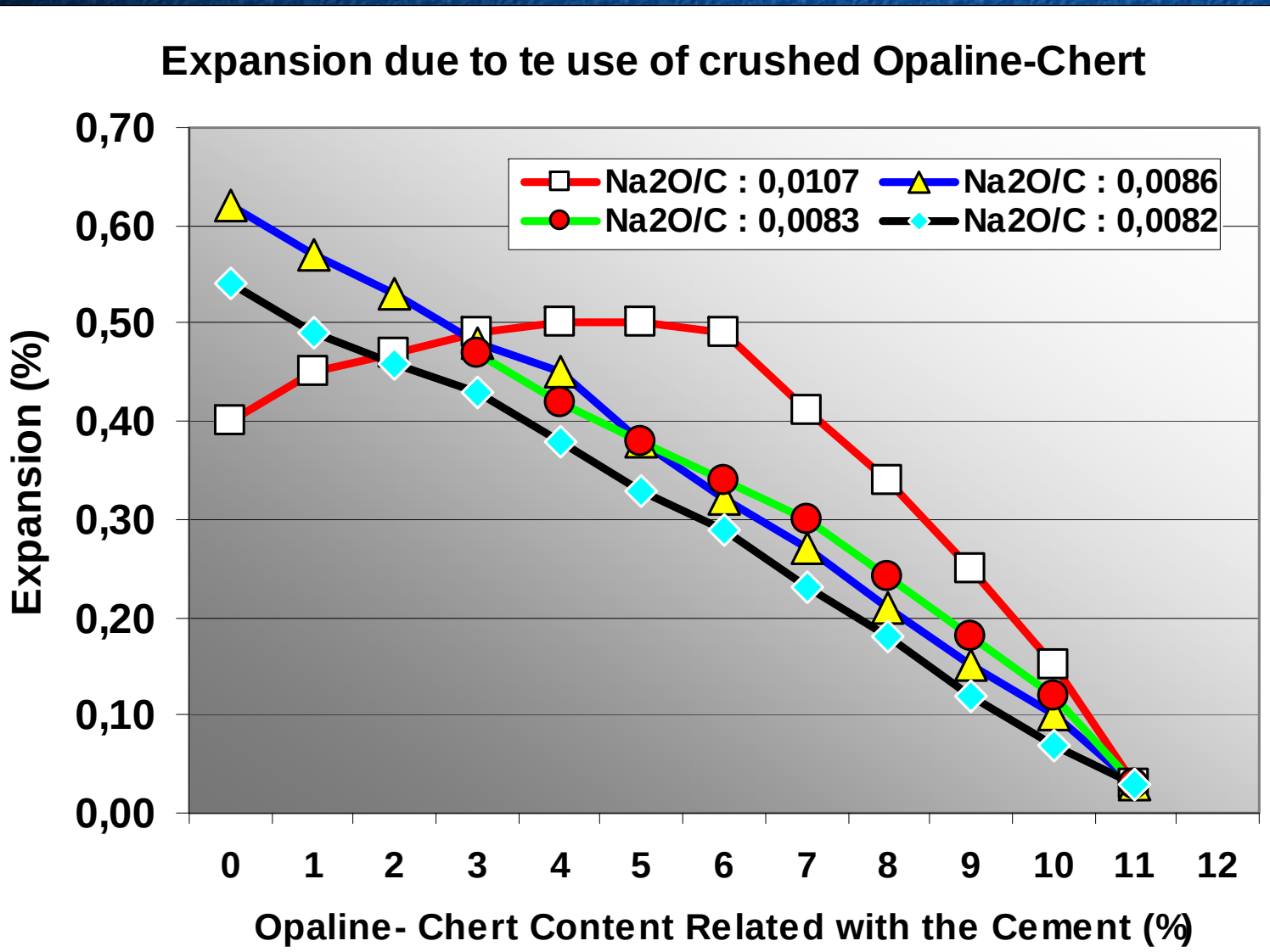
"…The particle size of this mineral also has an important bearing on the result. It was thought that, by crushing the deleterious particles to pass 200- mesh completely, an accelerated reaction might be had. The reverse was the case, as specimens fabricated with -80-mesh particles developed no expansion in sealed containers, whereas the – 30mesh to + 80 mesh particles specimens showed the greatest expansion (see Fig. 6(b))…

Therefore, it appears that the reaction between the reactive ingredient in the aggregate and the alkali in the cement, when the aggregate is in a finely divided state, is either dissipated throughout the mass in such a way as to cause no high expansive forces or the reaction is largely over before the concrete attains permanent set…."

POWERS T.C.; STEINOUR H.H. - **"An Interpretation of Some Published Researches on the Alkali-Aggregate Reaction- Part 2- A Hypothesis Concerning Safe and Unsafe Reactions with Reactive Silica in Concrete" – 1955 !!**

*"… **When the reactive mineral is powered, it can be used in a wide range of proportions without causing expansion. This was demonstrated by Vivian .** When opal was ground to pass the No. 300 sieve and **used in several proportions, expansion was practically zero for all proportions**. **The particle size of the reactive mineral is clearly an important factor…"***

"…When an aggregate contains reactive mineral and is used with an amount of alkali greater than it can tolerate, expansion can be prevented by adding an appropriate amount of pulverized reactive mineral, as has been shown by Hanna, Stanton, and others…."


Expansion due to te use of crushed Opaline-Chert
Na2O/C : 0,0107
Na2O/C : 0,0086
Na2O/C : 0,0083
Na2O/C : 0,0082
Expansion (%)
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
0
1
2
3
4
5
6
7
8
9
10
11
12
Opaline- Chert Content Related with the Cement (%)

QIGHAN, B.; XUEQUAN, W.; MINGSHUI, T.; NISHIBAYASHI, S; KURODA, T; TIECHENG, W.- **"Effect of Reactive Agregate Powder on Suppressing Expansions Due to Alkali-Silica Reaction"-** **1996**

"… The effect of reactive aggregate powder (Blaine's value 7,800cm2/g) on the expansion of mortars are substantiated….

…..It could be seen that for any alkali level, the expansion of mortars decreased remarkably with an increasing amount of powder, especially at high alkali levels…"

"…As a result, all of the above mentioned factors would contribute to the prevention of a detrimental reaction or to suppression of excessive expansion…"

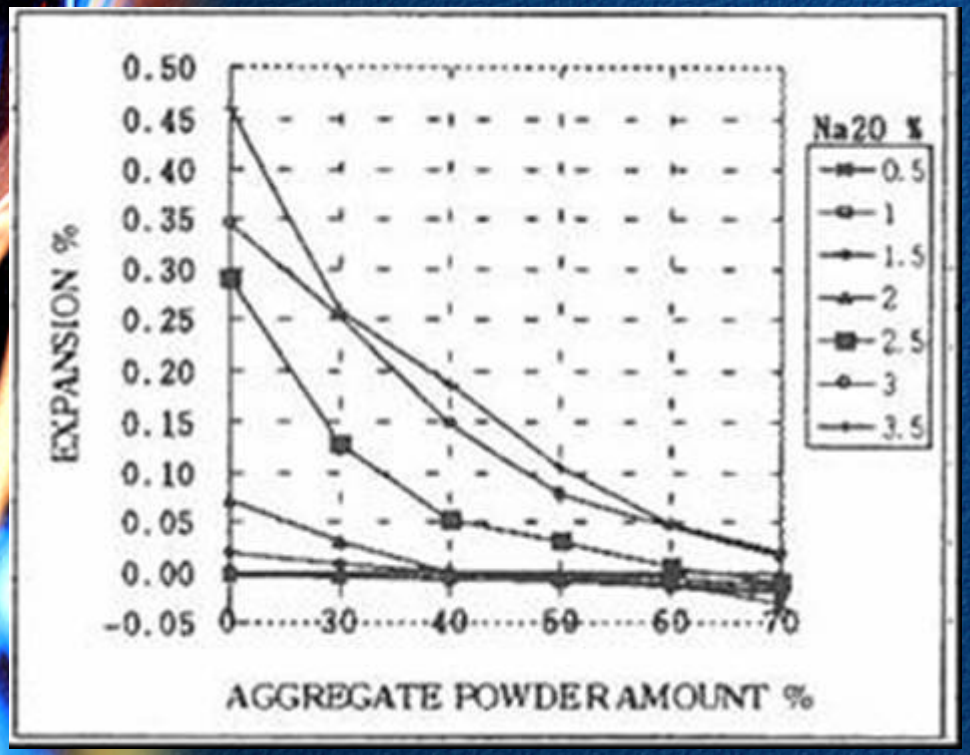
"… Evidently there is a sensitive fineness range of 5,640 ~ 8,045cm2/g to the expansion within it the variation of fineness will lead to an evident change of expansion becomes less sensitively in dependence of fineness. …" Fig-2

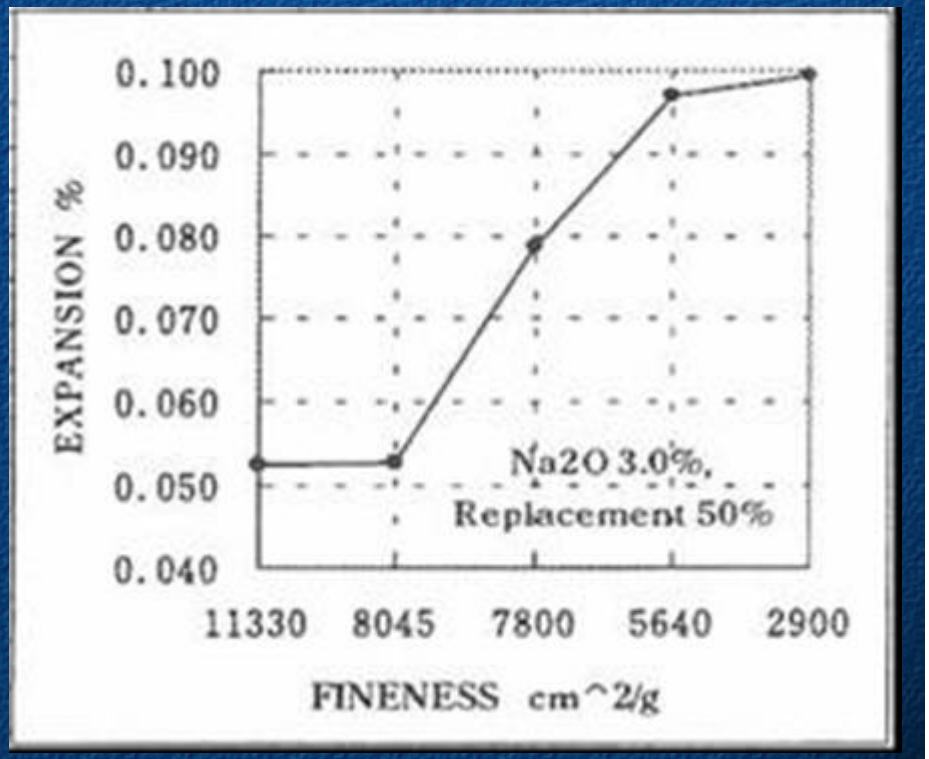
"…. All of these demonstrate that the powder could take part in the hydration reaction and improve the reaction rate. .."

CONCLUSIONS

"….The incorporation of reactive aggregate powder seems able to prevent mortars made of the same reactive aggregate sand from severe expansion, implying a promising approach to suppressing ASR…"

Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures





National (Brazilian) Ambit

In Brazil, from a historical perspective, the study of Rock Flour, or more precisely, rock fillers (particles lower than 0.075mm) were effectively begun in 1978 [9], whose results enabled its use in the concretes of the Urugua-i Dam in Argentina (in 1986 and reported in 1987) [10][11].

From that time on (1988) studies to gather information on the benefits of crushed/trituration rock fillers intensified at many Laboratories (ITAIPU; FURNAS; COPEL; CESP; CEMIG), as can be seen in the publications [13 to 27].

From the references mentioned, it is transcribed from [12] in Figure to follow.

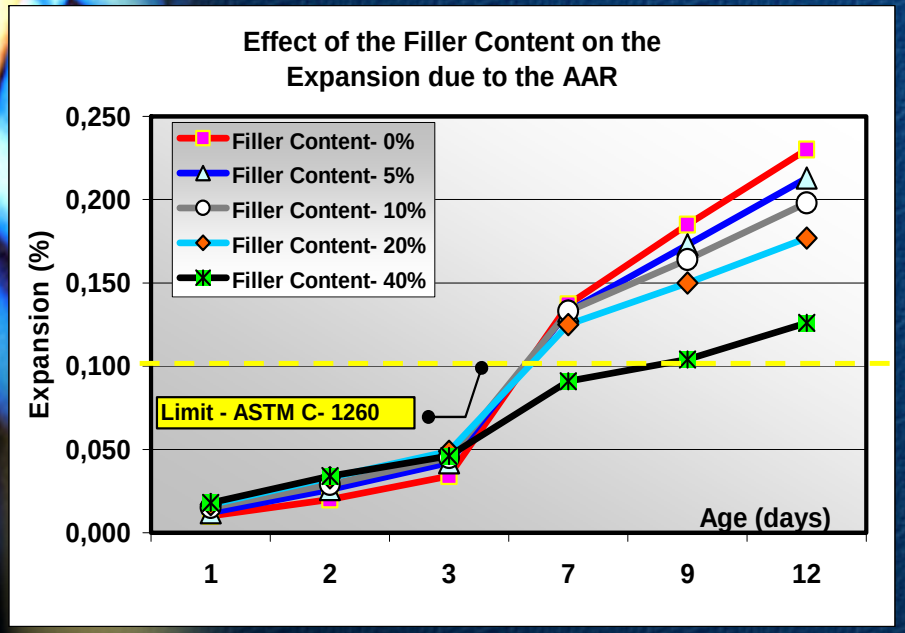
The references abridged in this text, proportional to about 15 years of research in reputed Brazilian Laboratories, reflects an enormous bulk of technical information that enables to extend the three traditional affirmations, of the same old matters already mentioned.

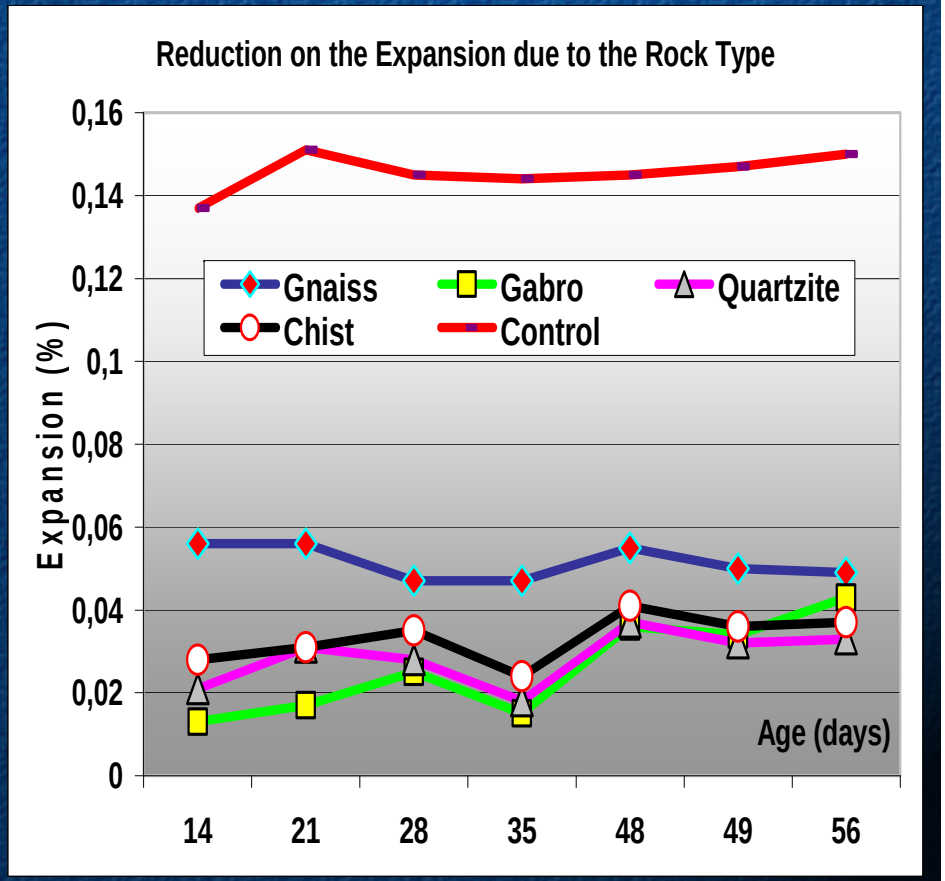
Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

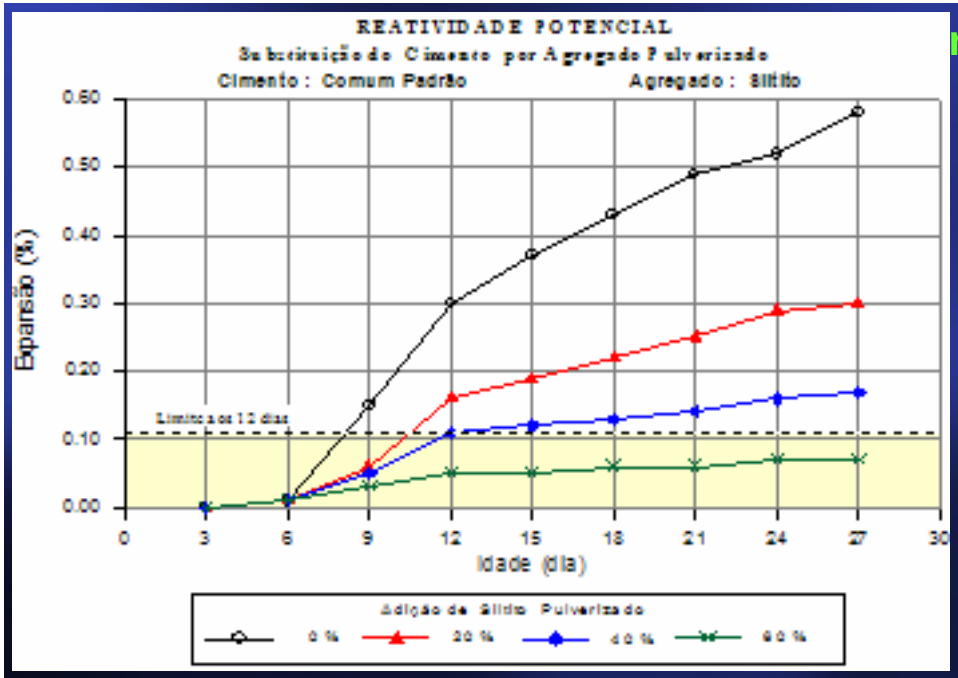
Sieve - mm	Crushed Sand Grain Size Meta-Sandstone- Capanda- Angola % Retained				
4- 4,8	1,1	1,0	1,0	0,9	0,7
8- 2,4	31,5	29,9	28,4	25,2	18,9
16- 1,2	19,1	18,1	17,2	15,3	11,5
30- 0,6	14,6	13,9	13,1	11,7	8,8
50- 0,3	11,2	10,6	10,1	9,0	6,7
100- 0,15	11,2	10,6	10,1	9,0	6,7
200- 0,075	11,2	10,6	10,1	9,0	6,7
< 200	0,0	5,0	10,0	20,0	40,0

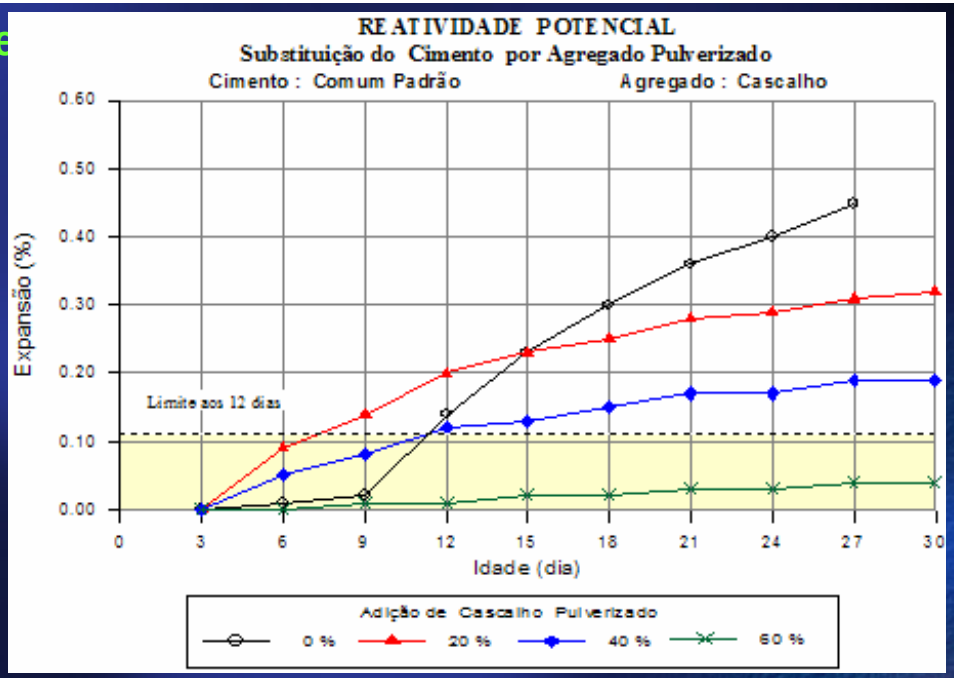
Age (days)	Expansion (%) Filler (< 0,075mm) Content (%) in the Crushed Sand				
	0	5	10	20	40
1	0,010	0,012	0,015	0,017	0,018
2	0,020	0,026	0,029	0,033	0,034
3	0,034	0,042	0,045	0,049	0,046
	0,137	0,133	0,133	0,125	0,091
	0,185	0,173	0,164	0,150	0,104
	0,230	0,213	0,198	0,177	0,126

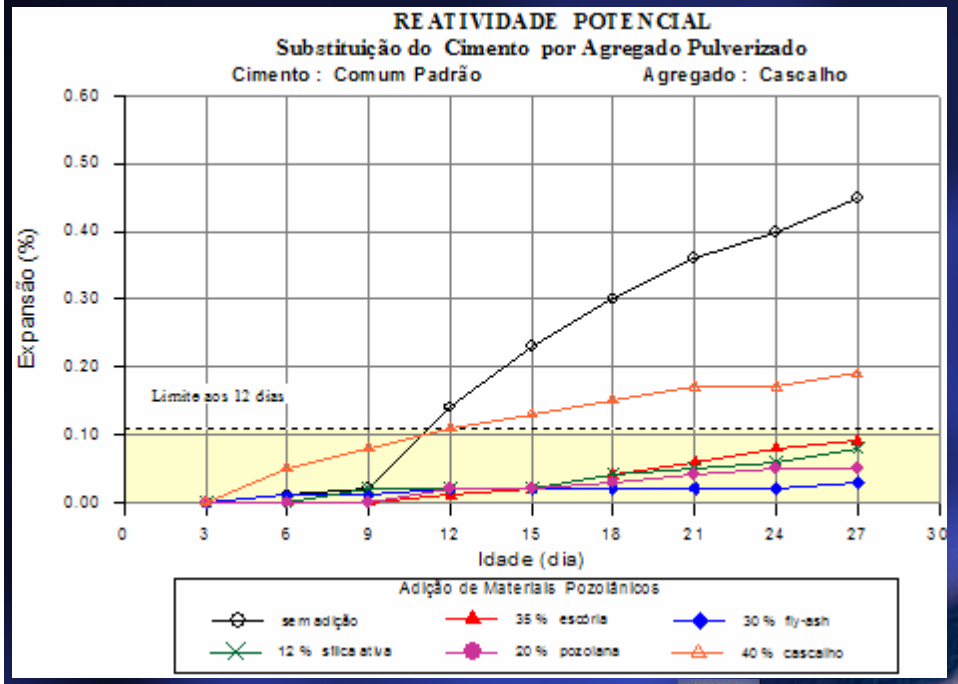
Rock Aggregate Type	Expansion (%) - Cement Alkali Equivalent= 1,2% Age (days) - Method ASTM C- 1260						
	14	21	28	35	48	49	56
Gnaiss	0,056	0,056	0,047	0,047	0,055	0,05	0,049
Gabro	0,013	0,017	0,025	0,015	0,036	0,034	0,043
Quartzite	0,021	0,031	0,028	0,018	0,037	0,032	0,033
Chist	0,028	0,031	0,035	0,024	0,041	0,036	0,037
Control	0,137	0,151	0,145	0,144	0,145	0,147	0,15











Tests performed by the FURNAS Laboratory

Part II- DEFENSIVE Procedures

The analysis of a Structure affected by AAR need be done with the intention to answer (at least):

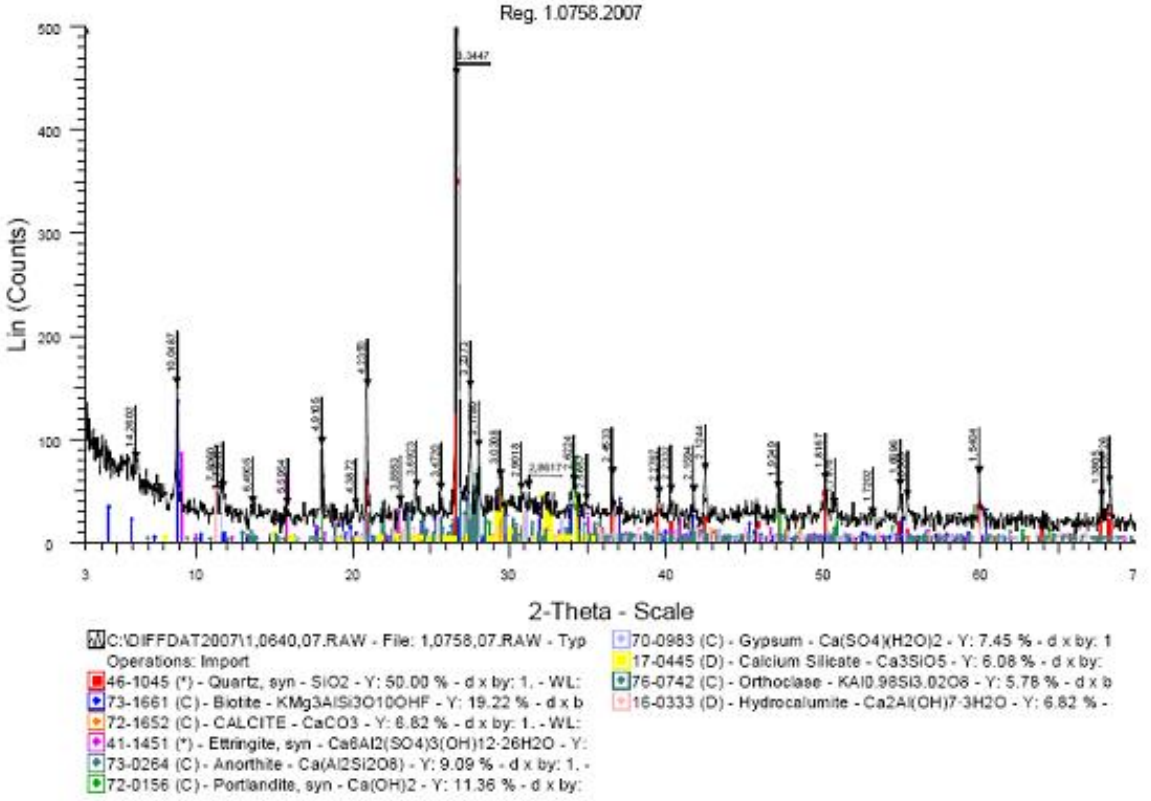
- Are there some Structural Reserve (Stability, Properties, and other aspects) ?
- How long the expansion will continue ?
- How big can be the future expansion ?

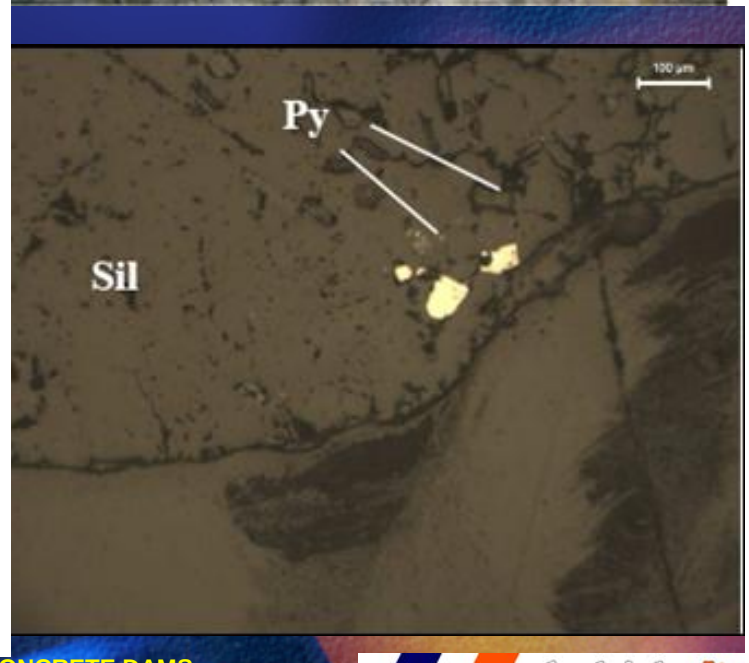
The Repair Actions (**Defensive Procedures**) need to be based on the Technical Research and Data.

The aspects of the future expansion – How Long and How Big, can be (!?) supported by Laboratory tests.

The Structural Reserve is the subject of this presentation

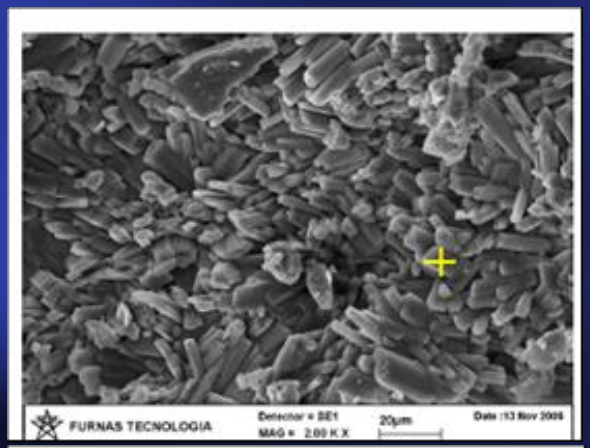
Laboratorial Aspects

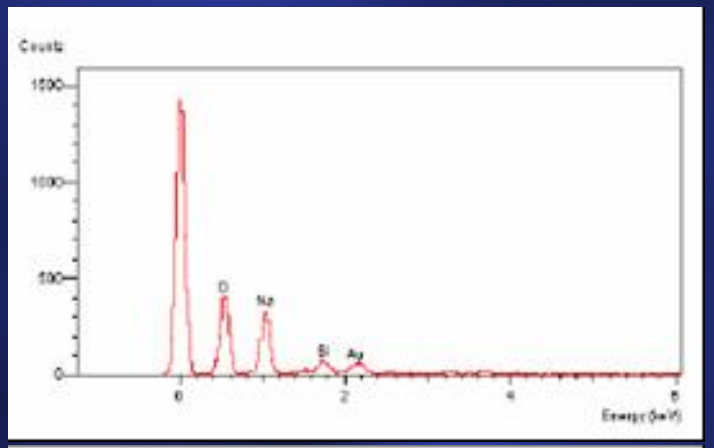


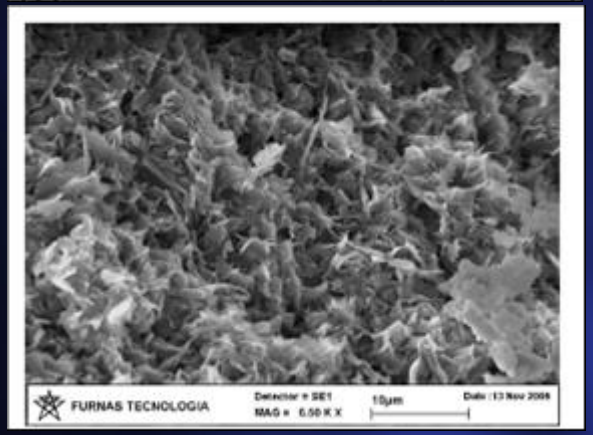


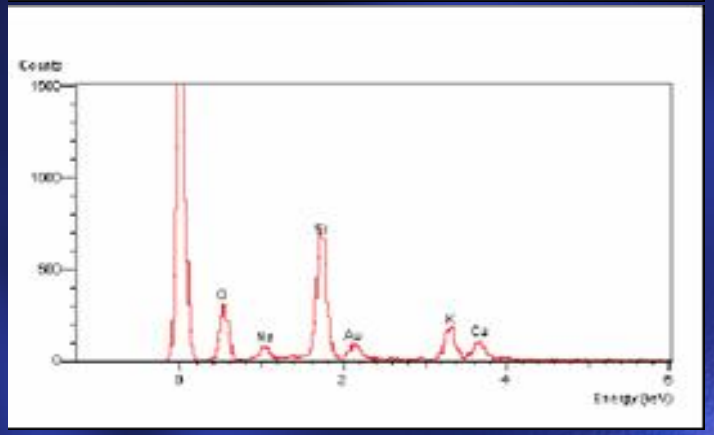
Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

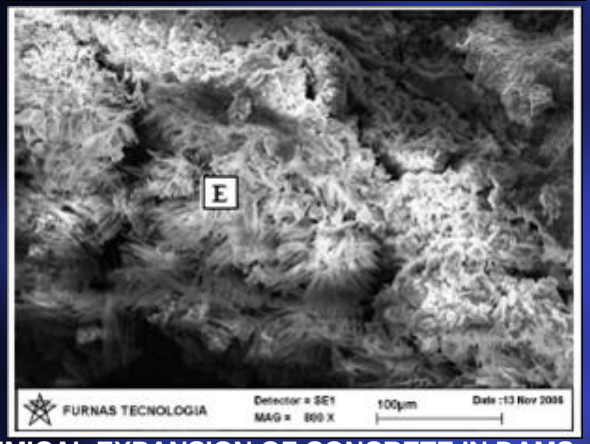
Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

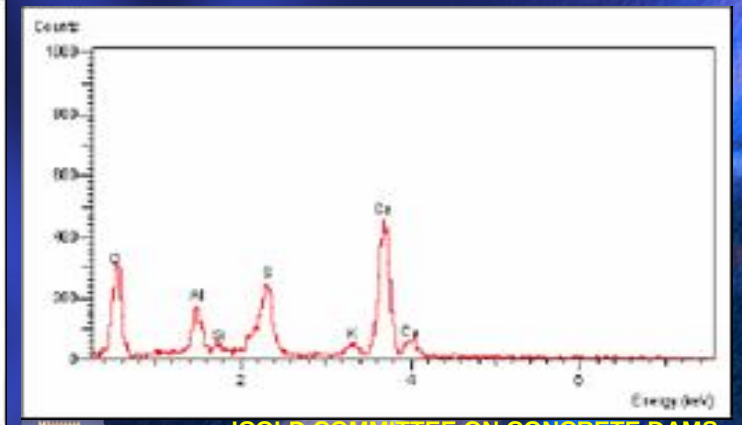






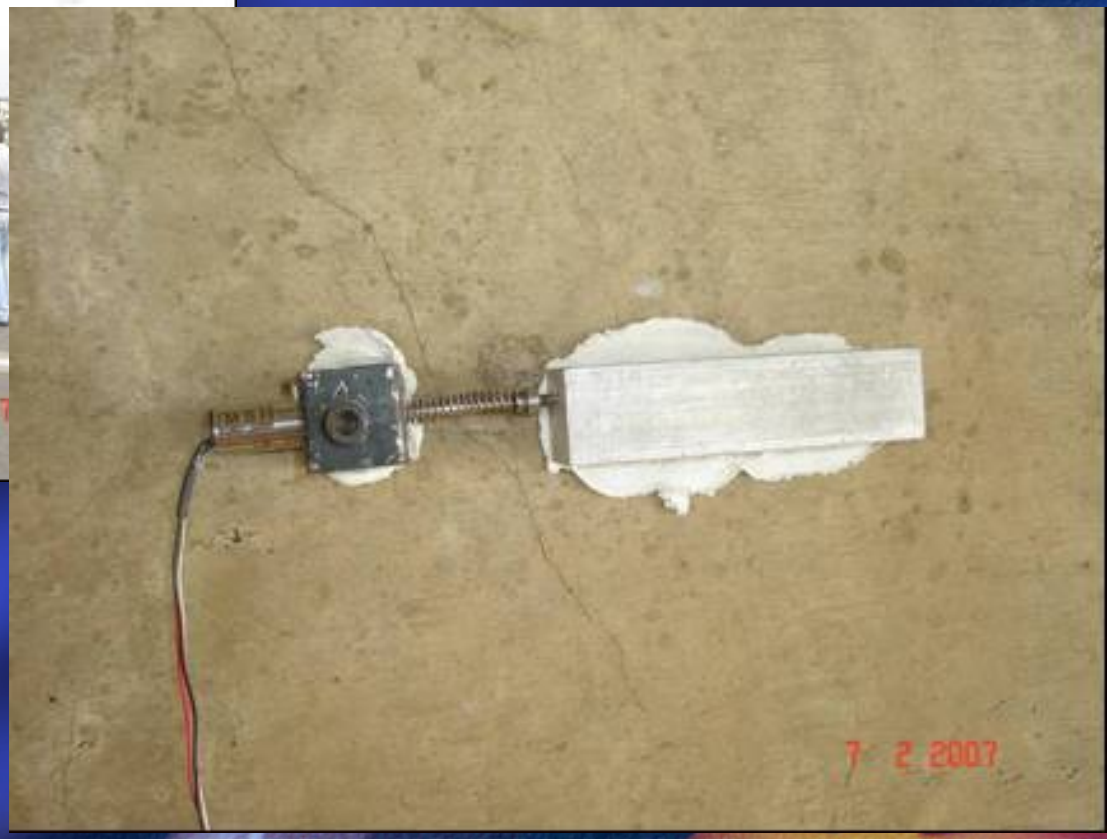






Monitoring – Displacements & Expansions

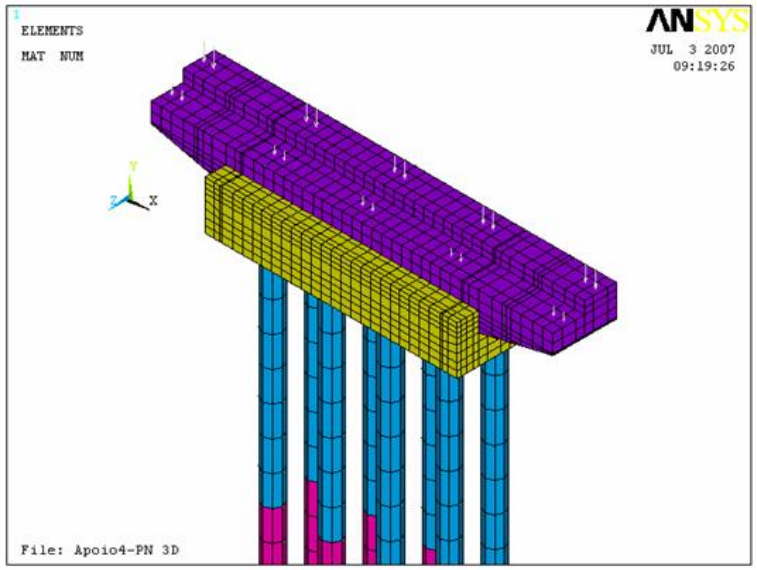
Static Load Test & Monitoring

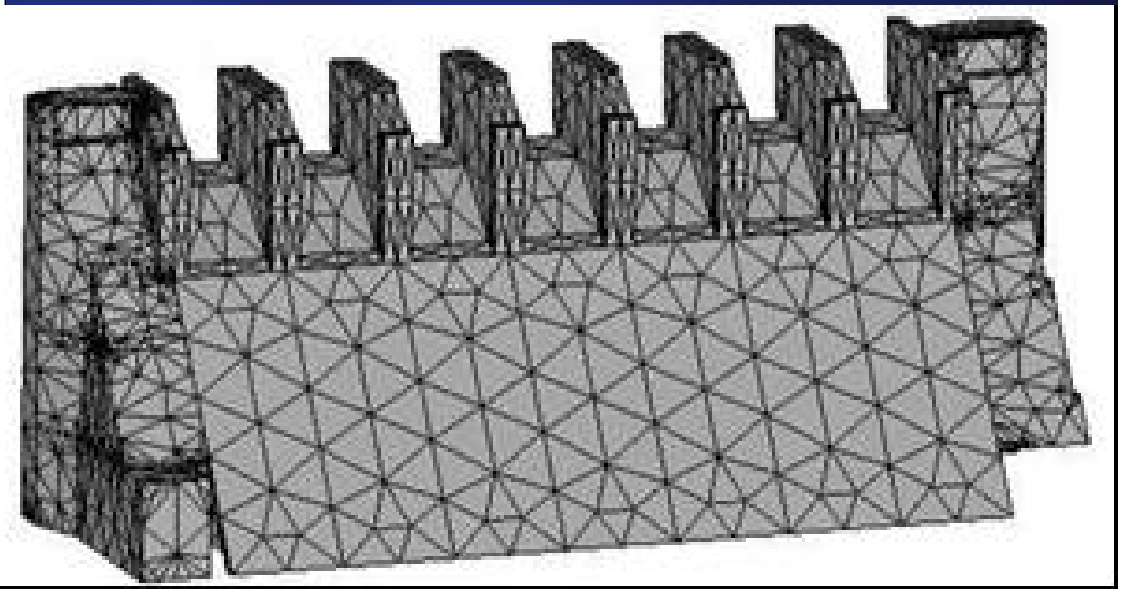


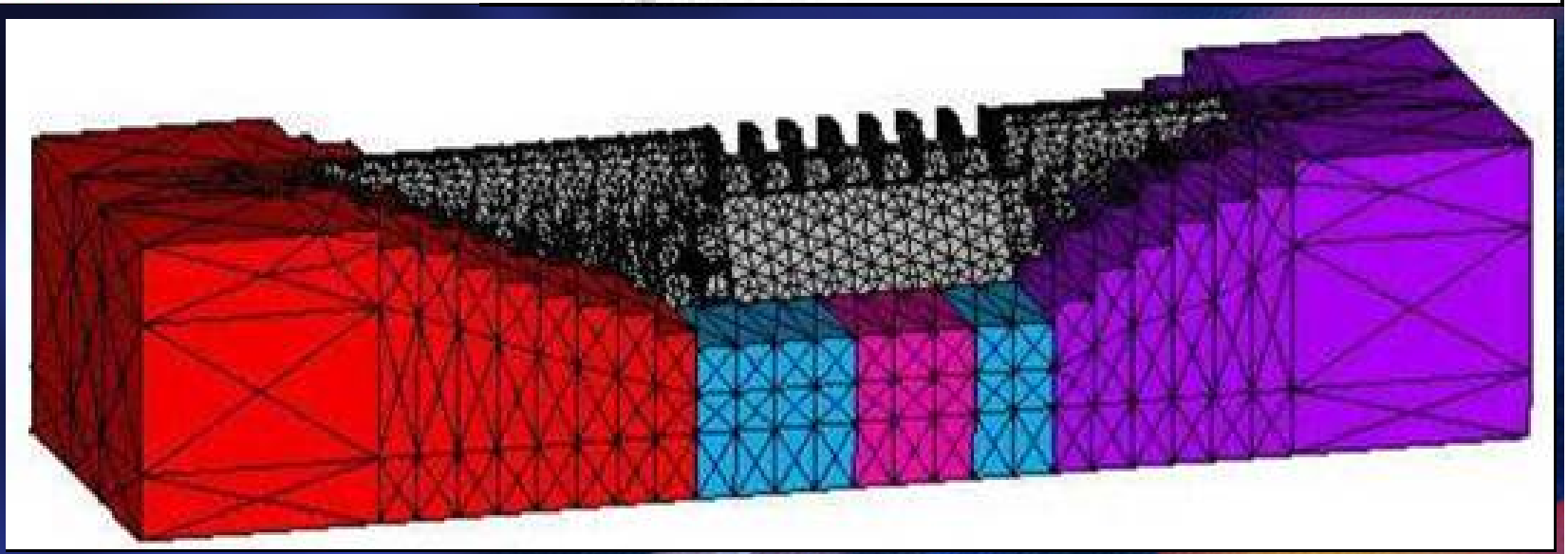
Dynamic Load Test & Monitoring

Natural Frequency

Mathematical Modeling





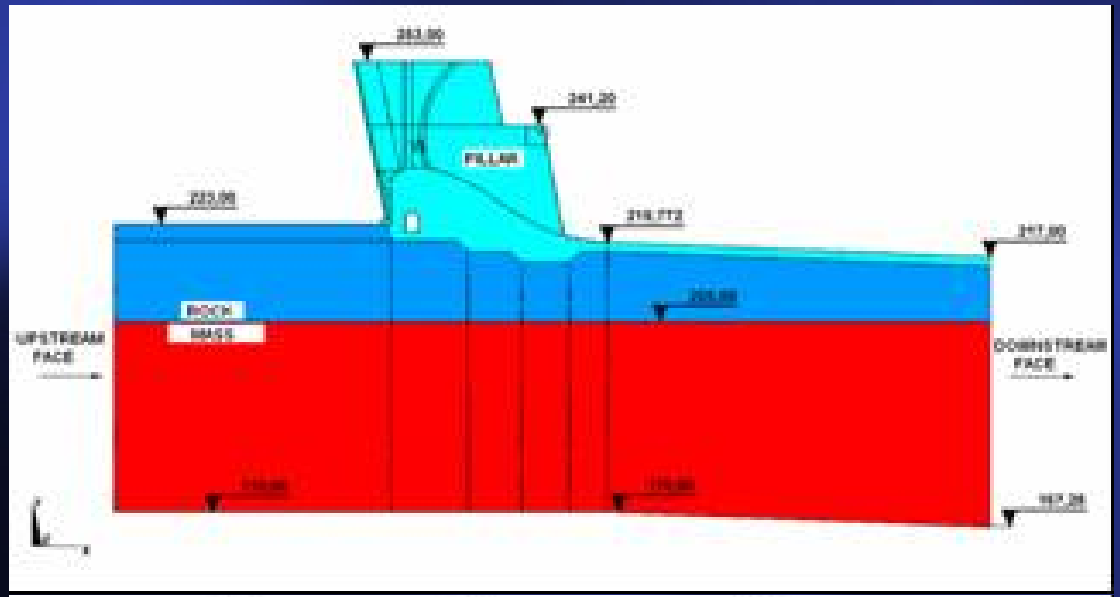


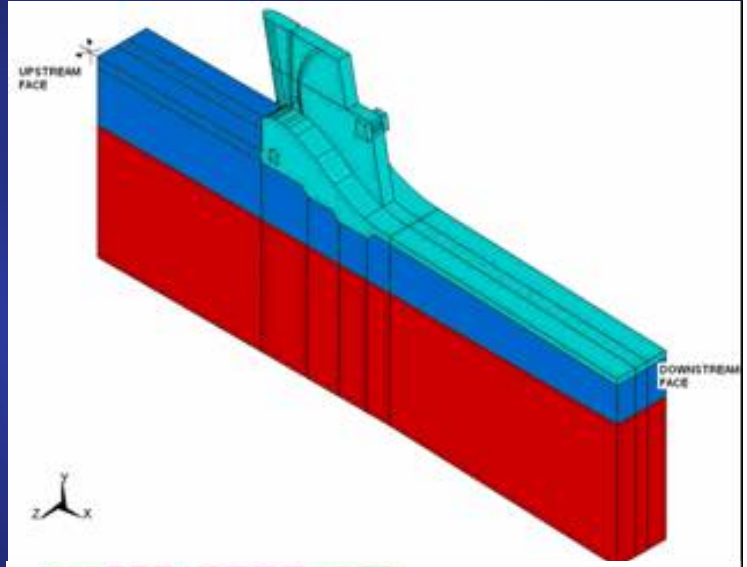
Part III- Example - Paulo Afonso IV - Spillway

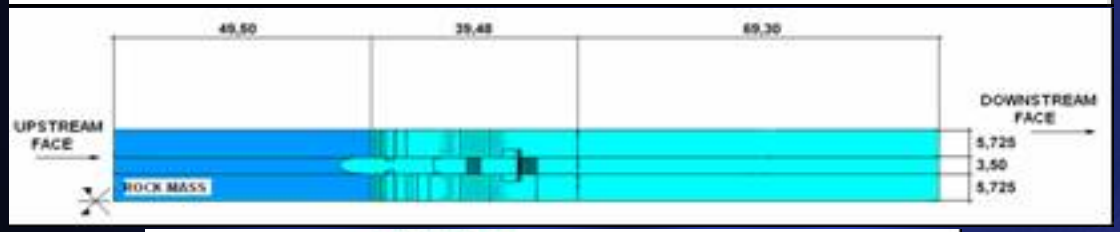
Spillway comprises 7 blocks and 2 side blocks containing a set of 8 overflowing sills, 7 pillars e two lateral walls.

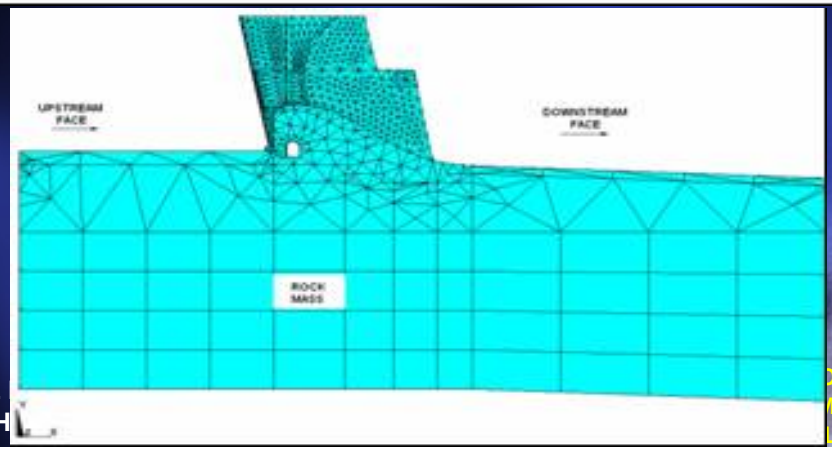
Construction Start Up	1972
Power	2,460 MW
Generators	06
Spillway Capacity	10,000m³/s
Concrete Volume	800,000m³

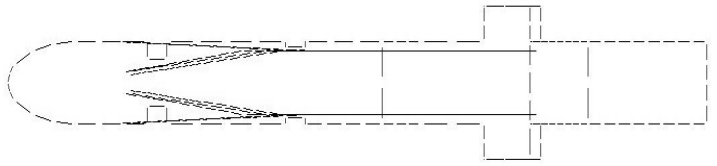
Mathematical Modeling











CHEMICAL & H

OMMITTEE ON CO
MITTEE ON CONCRETE FOR DAMS, and
L JOURNAL ON HYDROPOWER & DAMS

Engenharia

Material properties
Instantaneous Elastic Properties

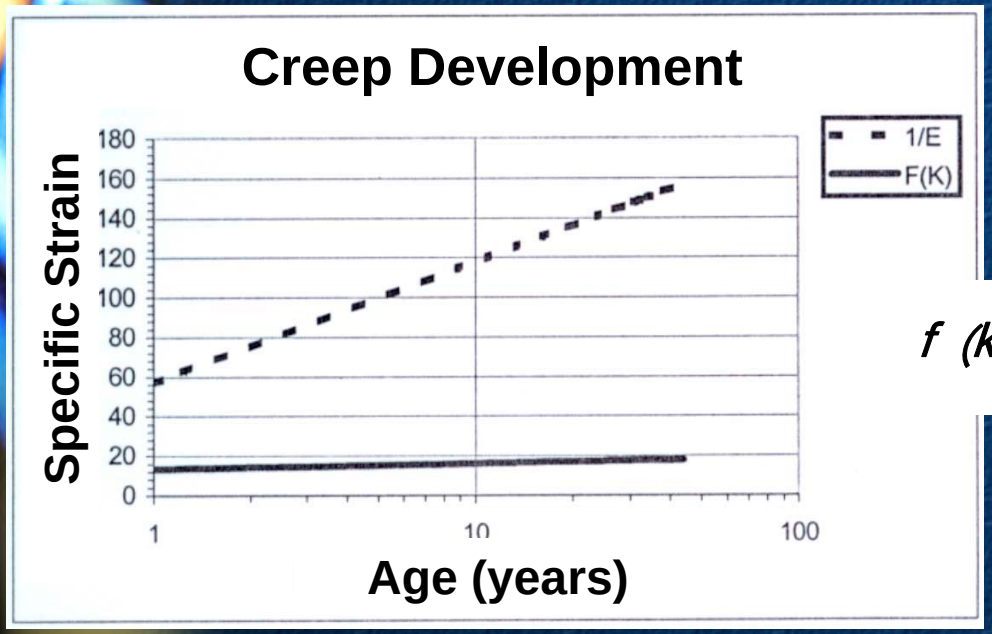
Parameters	Concrete	Steel	Rock mass above level 205,00 m	Rock mass below level 205,00 m
Elasticity Modulus (MPa)	30,000	19,500	10,000	20,000
Poisson's Ratio	0.17	0.3	0.2	0.2

Concrete expansion

Year of Operation	Saturated Concrete Expansion		Non-saturated Concrete Expansion	
	Horizontal Expansion με x/year and με z/year	Vertical Expansion με y/year	Horizontal Expansion με x/year and με z/year	Vertical Expansion με y/year
1st year	6	16	5.25	14
2nd year	12	32	10.50	28
3rd year	18	48	15.75	42
4th year	24	64	21.00	56
5th year	30	80	26.25	70

Expansion Rates

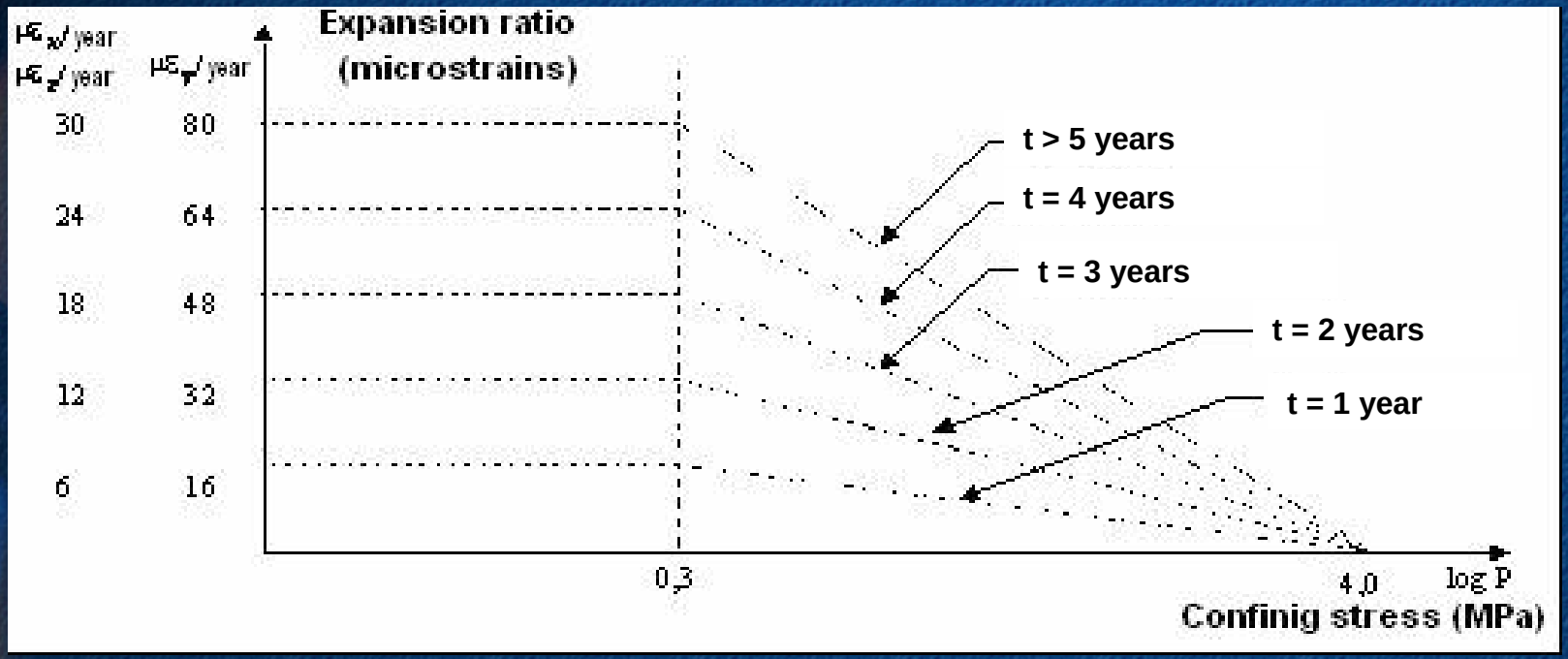
Index	Saturated Concrete	Dry Concrete
ε_{ov} (με)	80	70
ε_{oh} (με)	30	26,25
$\varepsilon_{ov}/\varepsilon_{oh}$	2,67	2,67
P_o (MPa)	4,0	4,0



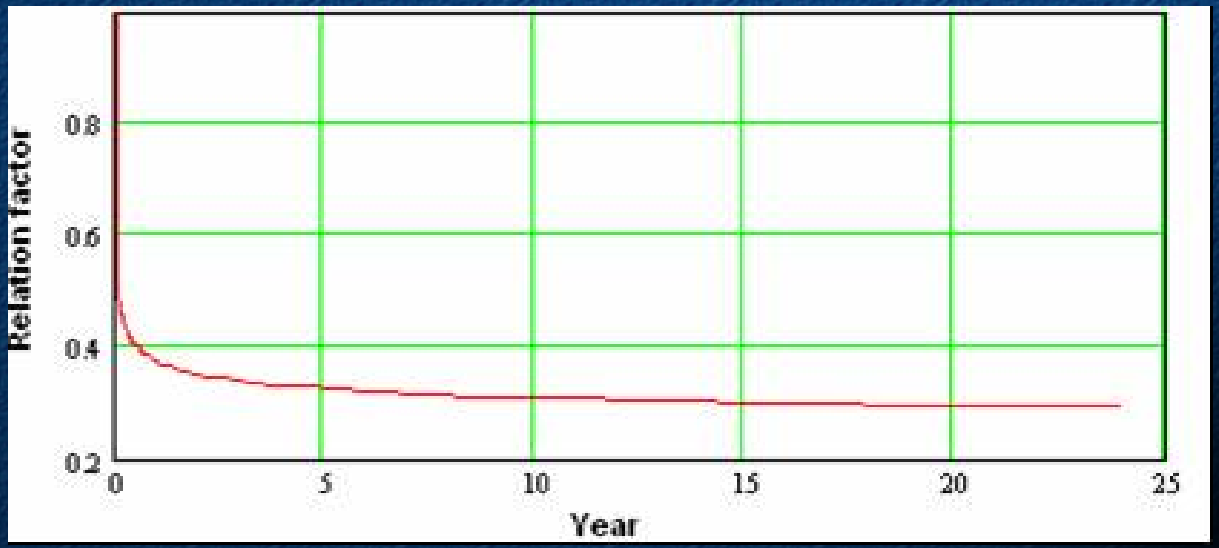
Concrete Viscoelastic Behaviour

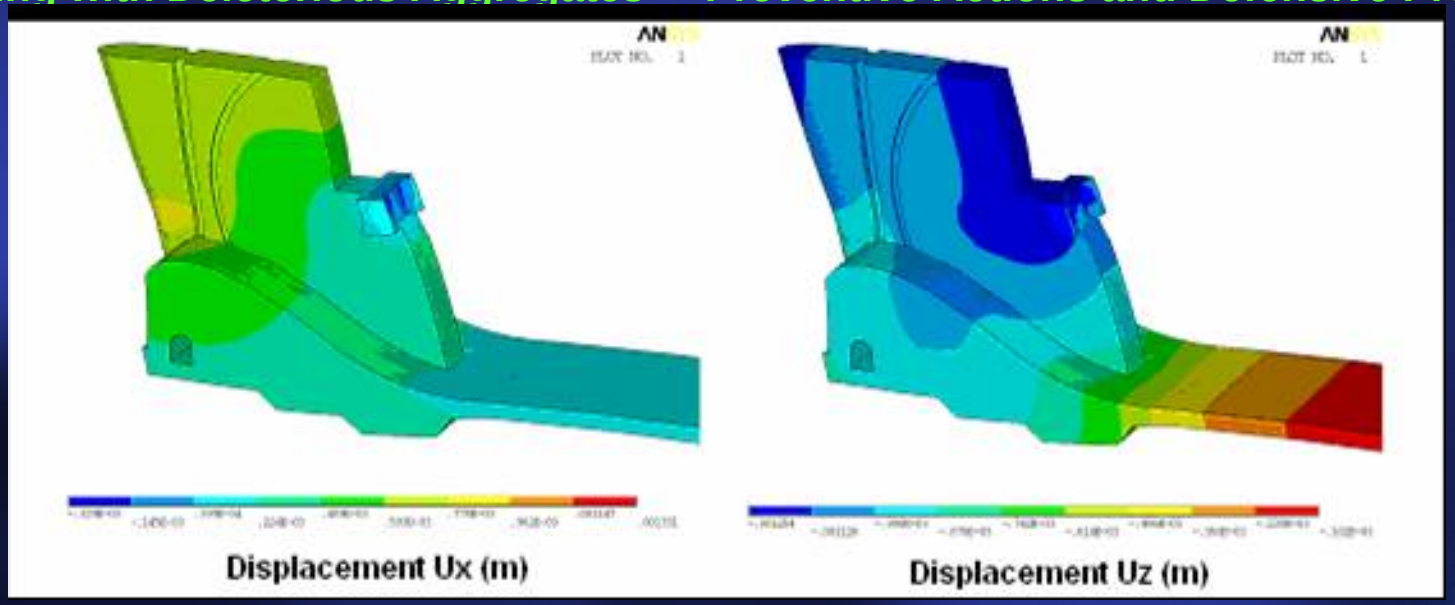
$$f(k, t-k) = \frac{1}{E(k)} + F(k) \cdot \ln(1 + t - k)$$

Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

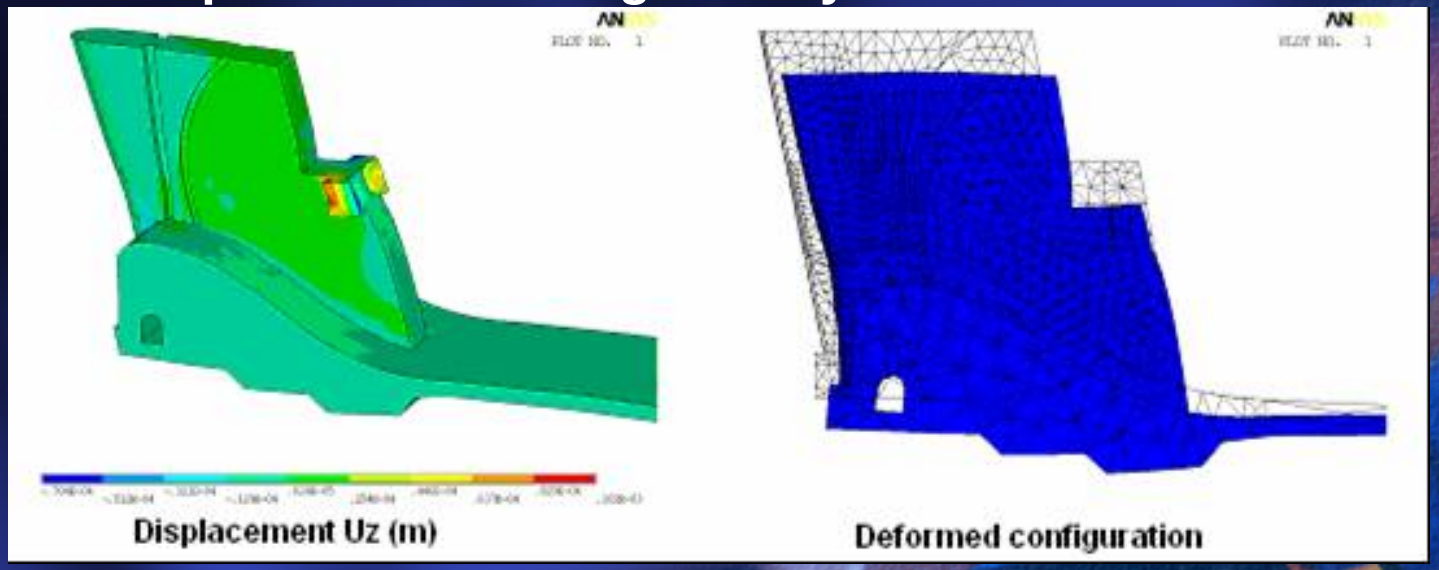


Creep parameters along the time

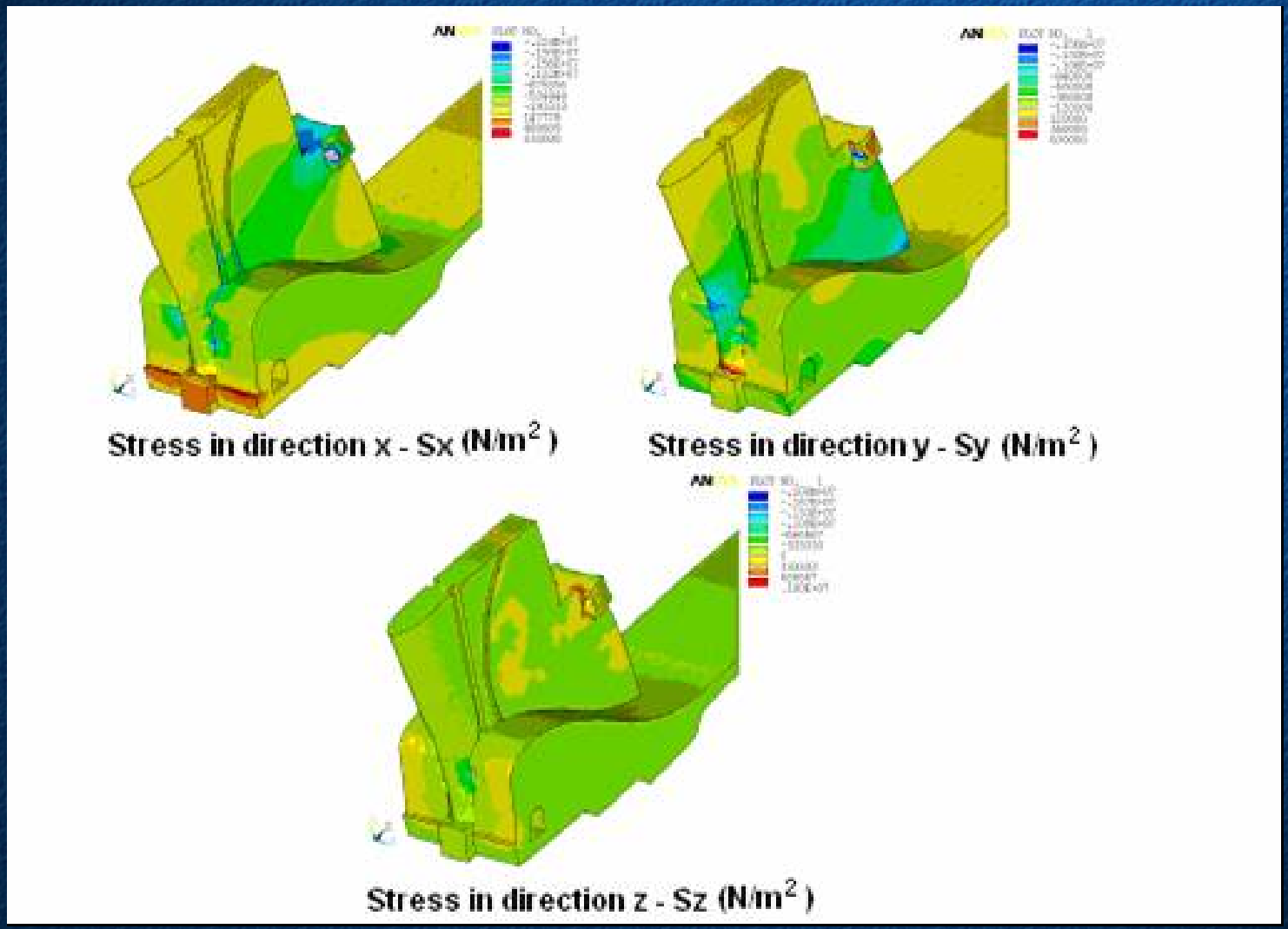




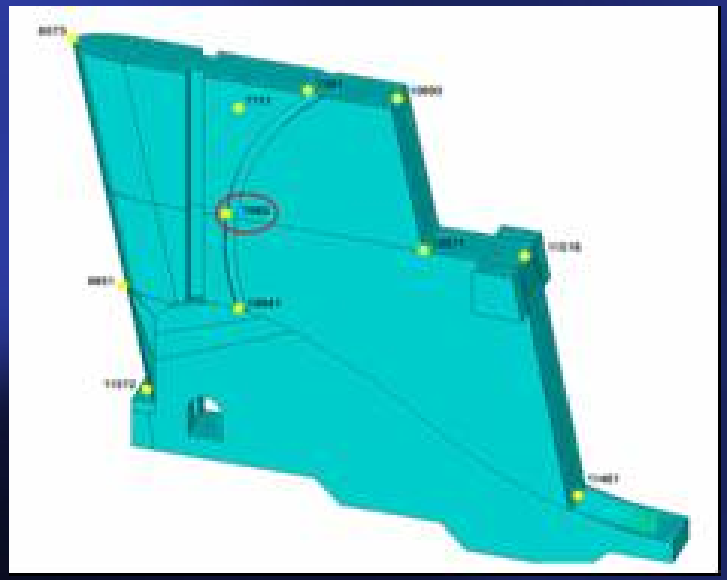
Displacements along x and y with initial load



Spillway deformed configuration

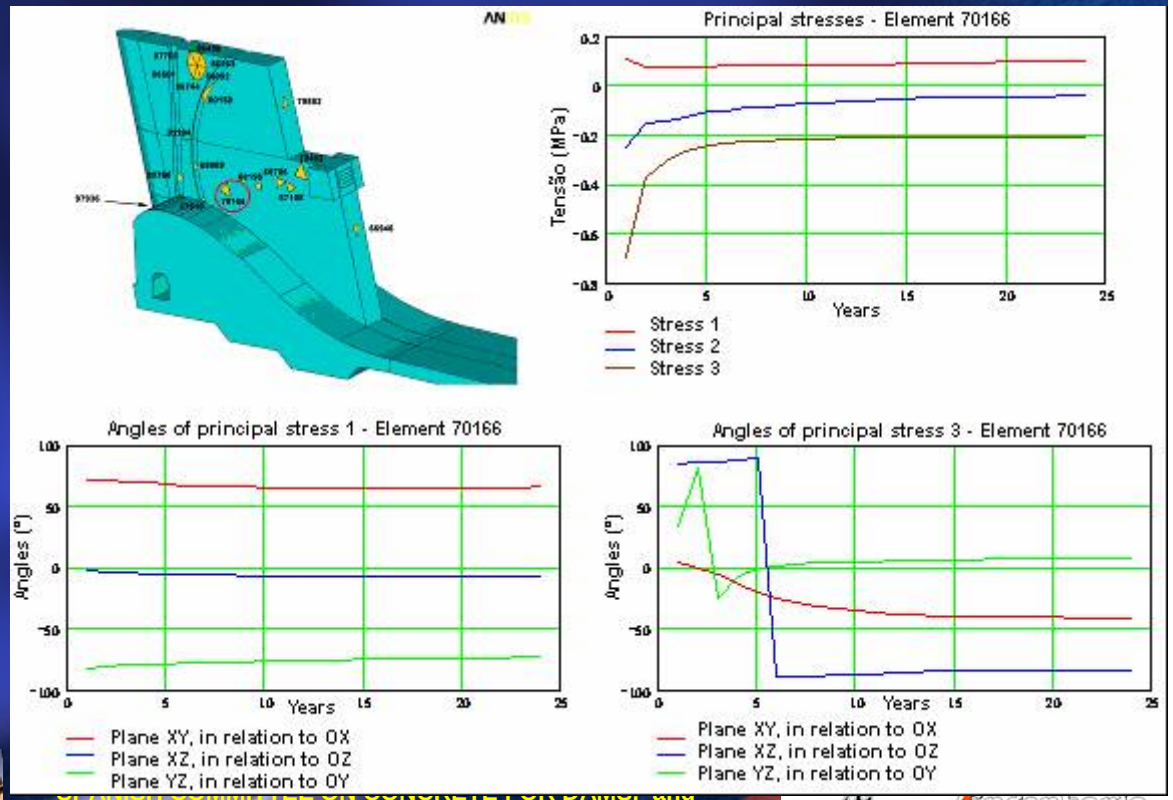


Spillway initial stresses

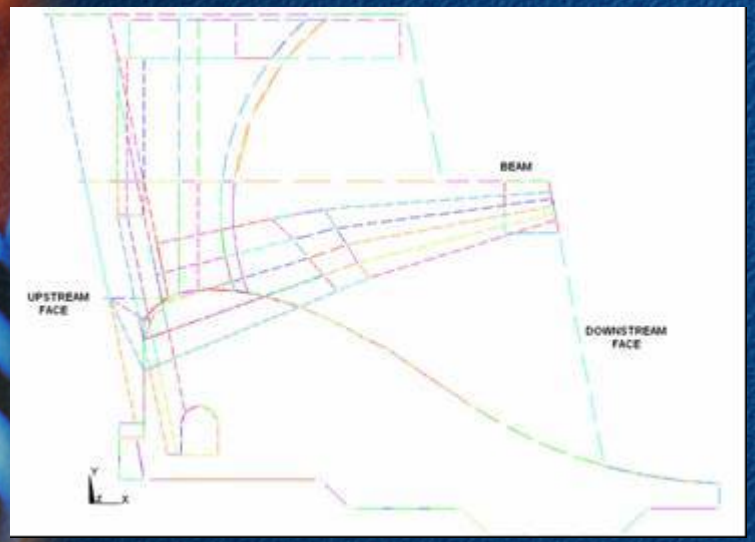


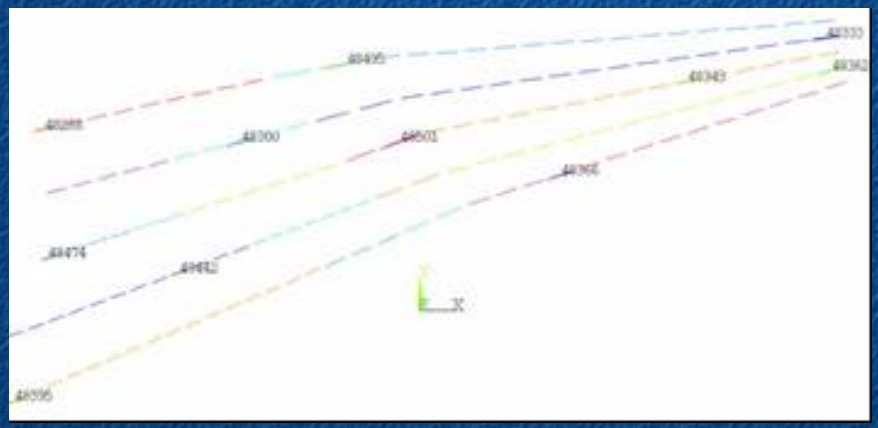
Monitored points along the time

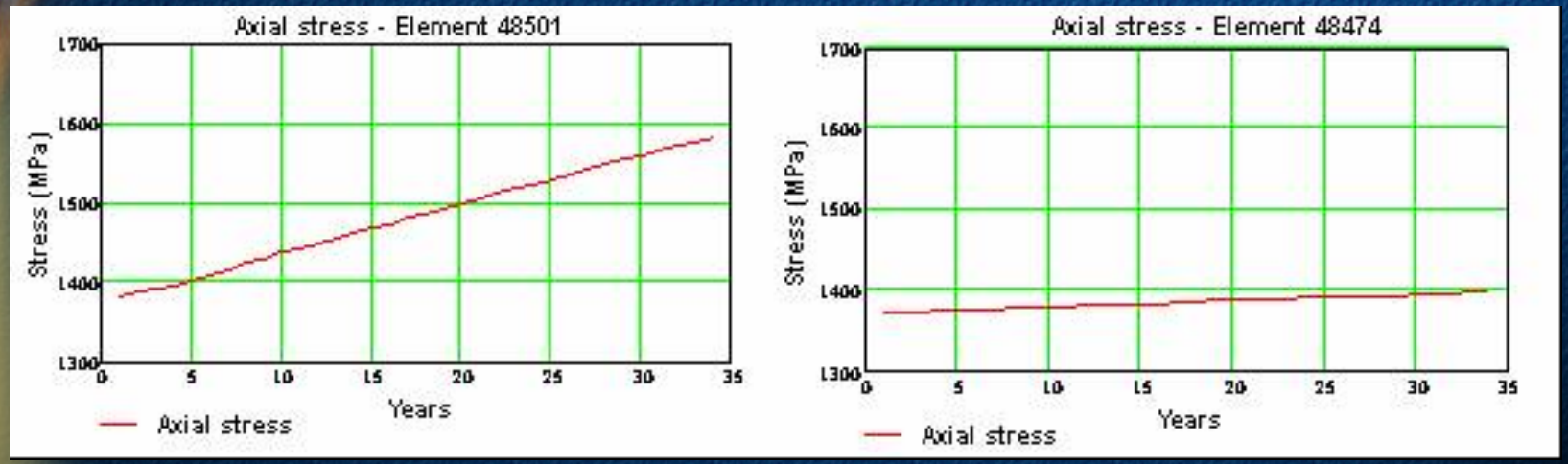
Expansion ratio for the element 70166



It has also been possible to evaluate a stress increase in pre-stressing tendons due to the AAR.







Pre-stressed Cables at Right Lateral Side

Comments, Suggestions and Conclusions

Preventive Actions

The huge bulk of technical data resulting from much research carried out in many important laboratories enables to state:

✓ There is a safe use of deleterious aggregates, grounded on assays that confirm reduction of expansion of these very aggregates, after crushing/trituration, which provides particles smaller than 0.075mm;
✓ It is advisable to evaluate these aggregates prior to use, by means of assays that can attest their safe use.

Resulting from these studies and aiming at having specifications that in a bureaucratic sense can restrict the use of aggregates, it is suggested:

Detailed elaboration, as mentioned in ASTM C 33, allows to prove that the use of a material – **that does not completely fulfill an item in the specification –** produces concretes **with relevant properties at least equal to the concrete with the same materials, however, that it fulfills the specifications completely .**

Defensive Procedures and Paulo Afonso IV Analysis

The results presented show the great influence of concrete expansion due to AAR on both displacements and stresses in Paulo Afonso IV Hydro Spillway structures. These results present, after 34 years, an increase in displacements and final stresses of up to 50 times compared to respective values for own weight and hydrostatic loading, including gate and pre-stressing loads.

A 60 mm final vertical displacement in the spillway crest was verified. Such displacement is compatible with estimated concrete expansion for 34 years.

Concrete stresses have topped around 0.4 MPa for tension on pillar side face, region between stop-log slots and at the gate. This values don't match observed cracking state, leading us to believe existing cracks within this region, in all pillars, have probably not occurred as a consequence of alkali-aggregate reaction. At the other analyzed locations, maximum values have occurred on pillar downstream face and are around 1.5 MPa. They match cracking state seen on structure.

According to pre-stressing design criteria, initial safety coefficient that considers driving losses is 1.33. Concrete expansion due to AAR along 34 year leads to an increase around 15% in axial stress in pre-stressing tendons, compared to initial stresses, rising up to maximum values of around 1600 MPa. Considering a friction and tendon relaxation generated 10 % loss on these maximum values, final safety coefficient reaches 1.31, being still compatible with initial design criterion.

As a whole, presented model, that has simulated the effects caused by concrete expansion due to AAR has shown results, strength and displacement values compatible with present Paulo Afonso IV Spillway structure shape. Thus, this model has shown to have conditions to be used as basis for a spillway monitoring project development.

Besides the analysis of spillway structural behavior as a whole, making a model has enabled the checking of stress increase along trunnion beam anchor tendons due to the reaction and has also enabled gate operation checking. **Based on strength and displacement levels reached in simulation for 34-year old structures, it has been concluded that the immediate adoption of correction measures is not necessary, but a calibration will be made for the model developed from both the readings of instruments that shall be further installed and concrete stress measurements.**

References

[01]- STANTON, THOMAS E.- **"Expansion of Concrete Through Reaction Between Cement and Aggregate"-** Transaction ASCE American Society of Civil Engineers- Papers- USA- 1940;

[02]- HANSEN, W.C.- **"Studies Relating to the Mechanism by Which the Alkali-Aggregate Reaction Produces Expansion in Concrete"-** Journal of the American Concrete Institute-Detroit- Michigan- USA- 1944

[03]- HANNA, W.C.- **"Unfavorable Chemical Reactions of Aggregates in Concrete and a Suggested Corrective"** Proceedings ASTM- American Society for Testing and Materials- Pennsylvania, USA- 1947

[04]- STANTON, T.E.- **"Studies of Use of Pozzolanas for Counteracting Excessive Concrete Expansion resulting from Reaction Between Aggregates and the Alkalis in Cement"** - Symposium on Use of Pozzolanic Materials in Mortars and Concretes- ASTM- Special Technical Publication- Pennsylvania, USA -1950

[05]- VIVIAN, H.E- **"Studies in Cement-The Effect of Small Amounts of Reactive Component in the Aggregate on the Tensile Strength of Mortar"-** Commonwealth Scientific and Industrial Research Organization, Melbourne- Australia- 1950

[06]-VIVIAN, H.E.- **"Studies in Cement-Aggregate Reaction: Effect on Mortar Expansion of the Particle Size of the Reactive Component in the Aggregate"-** Australian Journal of Applied Science- 1951

[07]- POWERS T.C.; STEINOUR H.H. - **"An Interpretation of Some Published Researches on the Alkali-Aggregate Reaction- Part 2- A Hypothesis Concerning Safe and Unsafe Reactions with Reactive Silica in Concrete"-** Journal of the American Concrete Institute- Detroit- Michigan- USA -1955;

[08]-P. BREDSDORFF; G,M.IDORN; A. KJAER; NIELS M. P.; E. POULSEN- **"Chemical Reactions Involving Aggregate"-** IV International Symposium –Chemistry of Cement-Washington-1960;

[09]- BRAGA, J.A.; ROSÁRIO ,L.C.; DUARTE, J.D.C.; LACERDA, S.S.- **"Utilização de Finos- Sub-Produto de Britagem nos Concretos Rolado e Convencional"**- XVIII Seminário Nacional de Grandes Barragens - Foz do Iguaçu- Brazil-1989;

[10]- GOTTARDO, G.; PEÑA, D.F.; ANDRIOLO, F.R.- **"Urugua- i : Uma Barragem em Conncreto Rolado"**- XVI Seminário Nacional de Grandes Barragens- Brasília- DF-Brazil- 1987;

[11]- GOLIK, M.A.; Andriolo, F.R.; - **"Urugua-i (CCR) - Controle de Qualidade do Concreto Lançado no Tramo Principal da Barragem"**- XVIII Seminário Nacional de Grandes Barragens - Foz do Iguaçu- Brazil-1989;

[12]- ANDRIOLO, F.R.; BRAGA, J.A.; ZANELLA, M.R.; ZALESKI, J.M.- **"Uso do Concreto Rolado; Projeto Capanda - Angola; Ensaios Especiais"**- XIX Seminário Nacional de Grandes Barragens - Aracaju- Brazil-1991;

[13]- **RC-04/87- Ensaios de Materiais para o projeto Capanda (Primeiro Relatório Periódico)** Relatório Interno do Laboratório da ITAIPU BINACIONAL-1987

[14]- Laboratório de FURNAS-**"Estudo de Inibidores de Expansão da Reação Álcali-Agregado-** II Seminário Goiano de Engenharia Estrutural- Goiania- Brazil- 1989

[15]-FONTOURA,J.T.F.; SANTOS, M.C.; BITTENCOURT, R.M.; PACELLI, W.A.-**"Estudo de Inibidores de Expansão da Reação Álcali-Agregado"-** 32ª. Reunião Anual do IBRACON- Fortaleza-CE- Brazil**-** 1990;

[12]- BRAGA, J.A.; ZANELLA, M.R.; ZALESKI, J.M.; ANDRIOLO, F.R.- **"Uso do Concreto Rolado- Projeto Capanda (Angola)- Ensaios Especiais"** XIX Seminário Nacional de Grandes Barragens- Aracaju- Brazil-1991;

[16]- Equipe Técnia do Laboratório de FURNAS – **"Estudo de Dosagens para Concreto Compactado a Rolo- Usina de Cana Brava"** Relatório de estudos Internos à Empresa de FURNAS Centrais Elétricas SA- 1991;

[17]- KREMPEL, A.F.; CREVILARO, C.C.; PAULON, V.A.- **"Adição de Pó ao Concreto como Fator Econômico e de Durabilidade"-** 34a. Reunião do IBRACON – Curitiba- Brazil- 1992

[18]- CARMO, J.B.M.; NASCIMENTO, J.F.F.; FONTOURA, J.T.F.; SANTOS, M.C..; TRABOULSI, M.A.- **"Aplicação de Concreto Compactado a Rolo com Adições"-** 35ª. REIBRAC- Reunião Anual do IBRACON- Brasília-DF- Brazil-1993;

[19]- Equipe Técnica do Laboratório Central da CESP- **"Efeito dos Finos do Pó de Pedra em Concretos"** Relatório de Estudos Internos à Empresa da CESP- Brazil- 1994;

[20]- SALLES, F.M.; OLIVEIRA, P.J.R.; ANDRIOLO, F.R.- **"Crushed Powder Filler-The Use on RCC and the Reduction of Expansion due to the Alkali-Aggregate Reaction"** - International Symposium on RCC Dams- Santander, Spain- 1995;

[21]- KREMPEL, A. F.; ANDRIOLO, F.R- "**The Use of basaltic Crushed Powder (Filler) in the RCC"** International Symposium on RCC Dams- Santander, Spain- 1995;

[22]- ANDRIOLO, F.R.- **"El Uso de Materiales de Rejecto en el Hormigón"-** X Congreso Iberoamericano del Hormigón Premezclado- Quito-Ecuador- 1996;

[23]- QIGHAN, B.; XUEQUAN, W.; MINGSHUI, T.; NISHIBAYASHI, S; KURODA, T; TIECHENG, W.- **"Effect of Reactive Aggregate Powder on Suppressing Expansions Due to Alkali-Silica Reaction"** X International Conference on Alkali-Aggregate Reaction- Melbourne – Australia-1996;

[24]- ALVES, E.F.R.; CARMO, J.B.M.; SANTOS, M.C.; TRABOULSI, M.A.; - **"Estudo Comparativo da Expansão o Concreto e Argamassa Moldados"-** Simpósio sobre Reatividade Álcali-Agregado em Estruturas de Concreto-Goiânia- Brazil- 1997;

[25]- SALLES, F.M.; OLIVEIRA, P.J.R.; ANDRIOLO, F.R.- **"Uso de Finos de Britagem como Redutores da Expansão Devida à Reação Álcali-Agregado"** Simpósio sobre Reatividade Álcali-Agregado em Estruturas de Concreto-Goiânia- Brazil- 1997;

[26]-ANDRIOLO, F.R.- Estudos para escolha do Cimento para a Obra de Itá- Relatório Interno da Organização Odebrecht para a Obra do AHE Itá- Brasil- 1997;

[27]-CASTRO, C.H.; SANTOS, M.C.; TRABOULSI, M.A.; BITTENCOURT, R.M.- **"Influência do Agregado Pulverizado na Reação Álcali-Agregado"-** Simpósio sobre Reatividade Álcali-Agregado em Estruturas de Concreto-Goiânia- Brazil- 1997**;**

[28]- ABNT-NBR- 7211- **Agregados para Concreto**- Maio-Brazil- 2005

[29]- ASTM –C- 33- **Standard Specification for Concrete Aggregates**

[30]- ANDRIOLO, F.R.- **"Usos e Abusos do Pó de Pedra em Diversos Tipos de Concreto"**- IISUFFIB- Seminário- O Uso da Fração Fina da Britagem- Abril- São Paulo- Brazil- 2005 ;

[31]- HALICI, M. - **"Study of Cementitious Materials for Use in Mass Concrete of Deriner Dam & Hepp"**- State Hydraulic Works- Internal Report from the Research & Quality Control Department- Esenboga- Ankara-Turkey-2002

[32] CAVALCANTI, A J C T, JULIANI, M A, IGUTI, E T, HAHNER, I, ZUNIGA, J E. (2004) – **"AAR Effects at the Paulo Afonso IV Power Intake**"-. 12 International Conference in Alkali-Aggregate Reaction, Beijing, 2004. China.

[33] LARIVE, C. (1998) – **Apports Combines de Léxperimentation et de la Modélisation à la Comprehension de L'Alkali-Réaction et de ses Effects Mécaniques**, Décembre 1998 – LCPC, France.

[34] SOUZA LIMA, V. M.; GUEDES, Q. M.; ANDRADE, W. P. e BASTOS, J. T. (1979) – "**Cálculo da Relaxação de Tensões a Partir da fluência do Concreto"-** Revista Construção Pesada, Setembro/1979- Brazil.

Muchas Gracias y Buena Suerte a TODOS !!!

Surviving with Deleterious Aggregates – Preventive Actions and Defensive Procedures

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