

# RCC 2008 50 CBC - CONFERENCE

RCC PROPERTIES: WHAT IS MORE IMPORTANT FOR  
DAMS?

- *Opus Caementitium Adstrinctum (OCA)*

*Quod est máxima proprietas OCA: ?*

By Walton Pacelli de Andrade

# RCC 2008 50 CBC-CONFERENCE

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- PERMEABILITY
- SHEAR
- CORE DRILLING
- CCR –BRAZILIAN STANDARDS

# INTRODUCTION

- **-General**

The significant material properties of hardened RCC include: unit weight compressive strength, tensile strength, modulus of elasticity, tensile strain capacity, Poisson's ratio, biaxial and triaxial shear strength, volume change (thermal, drying, and autogenous), thermal coefficient of expansion, specific heat, creep, thermal conductivity, diffusivity, permeability and durability.

- Differences between the hardened properties of RCC and conventional concrete are primarily due to differences in mixture proportions, gradings, and voids content. A wide range of RCC mixtures can be designed, just as there is a wide range of mixtures for conventionally placed concrete. It is difficult to quantify typical values for either of them. In general, RCC will have lower cement, paste, and water contents and no entrained air. It also may use silt or other nonplastic fines to fill aggregate voids.

**ICOLD**  
**CONCRETE MATERIALS FOR DAMS**  
DRAFT 01A-

- Aggregate quality, grading, and physical properties have a major influence on the physical properties of conventional concrete. They can be even more important in RCC. Because some RCC mixtures use marginal or inferior aggregate (by conventional standards), the range in properties of RCC goes well beyond the range of normal properties for conventional concretes.

- The in situ properties of roller compacted concrete depend on the quality of the materials used, or the proportions of the mixture and on the grade of compaction that is achieved. Very diverse mixtures have been employed, going from lean mixes to mixes with a high paste content, the values obtained in a series of properties have also varied very extensively. The properties which depend on the nature of aggregates , such as their elastic or thermal characteristics, are seen to be influenced by these latter in a similar manner as that which occurs in conventional concretes.

# Laboratory Facilities for RCC



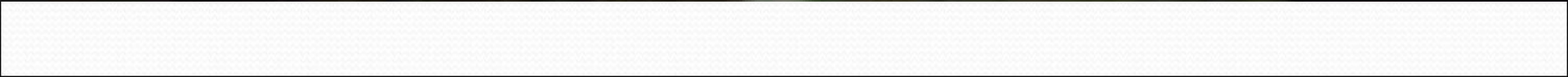


# DESENVOLVIMENTO DO EQUIPAMENTO DE SIMULAÇÃO DO CCR EM LABORATÓRIO

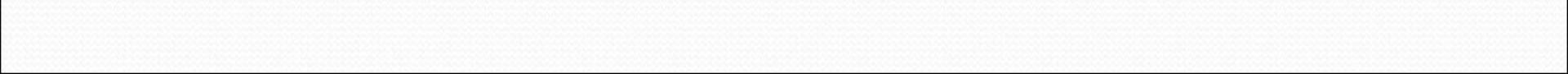
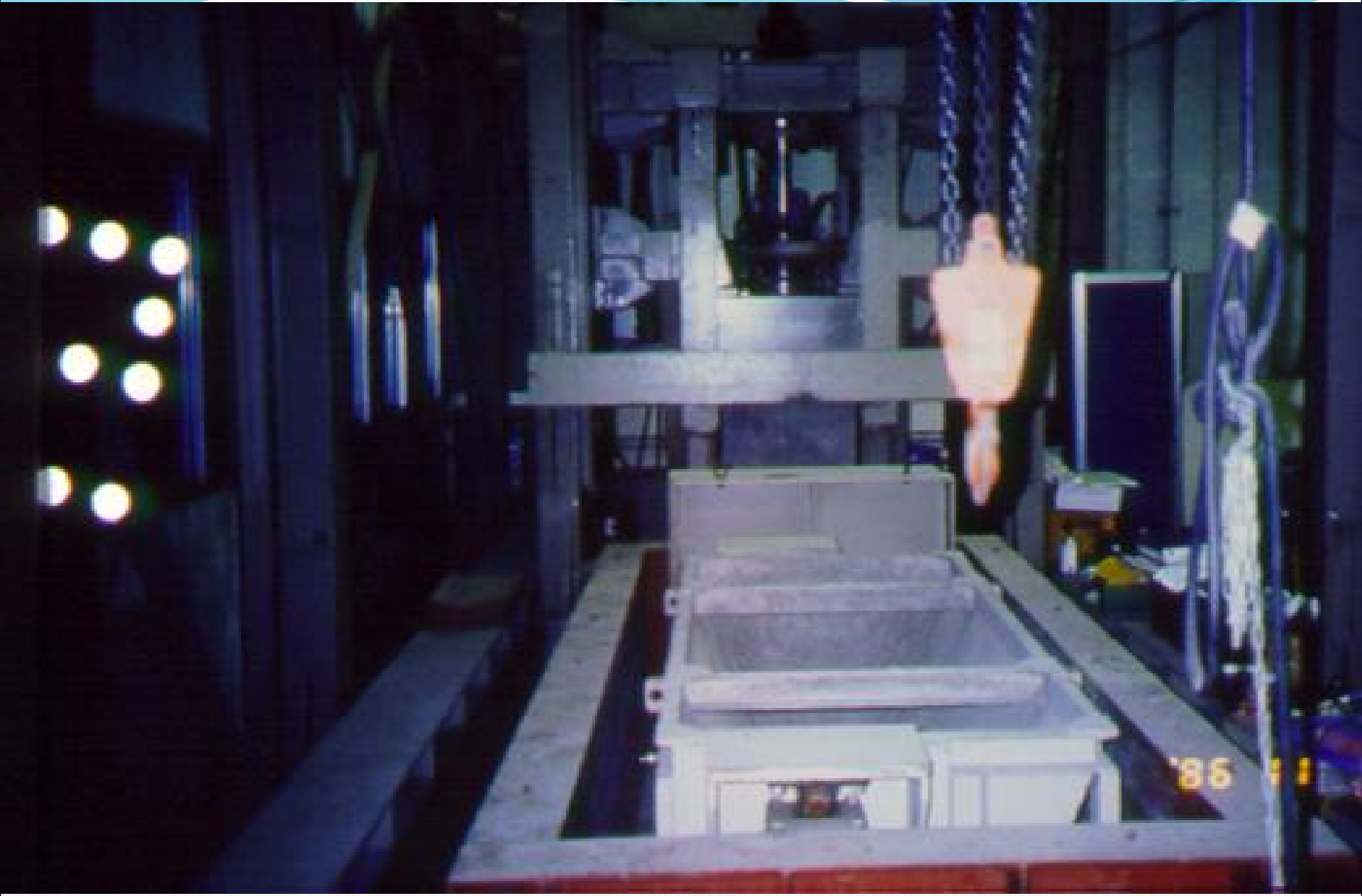
## DESENVOLVIMENTO DO EQUIPAMENTO DE SIMULAÇÃO DO CCR EM LABORATÓRIO

- 52nd ICOLD TOUR, MAY 1984 NO JAPÃO
- VISITA AO CENTRAL RESEARCH INSTITUTE OF ELECTRIC POWER INDUSTRY - CRIEPI
- CIVIL ENGINEERING LABORATORY
- TENTATIVAS DE COMPRAR O EQUIPAMENTO NO JAPÃO
- TENTATIVAS DE MEDIAÇÃO pelo Eng. Paulo Fernando Vieira Souto Rezende da Eletrobrás, para empréstimo ou doação do equipamento do CRIEPI









# DESENVOLVIMENTO DO EQUIPAMENTO DE SIMULAÇÃO DO CCR EM LABORATÓRIO

- ESTUDOS INICIAIS DO DESENVOLVIMENTO DE UM ANTEPROJETO EQUIPAMENTO DE VIBRAÇÃO pelo Eng. Ricardo Damião Sales Goz da Escola de Engenharia de Itajubá.
- .DESENVOLVIMENTO DE UM ANTEPROJETO DO EQUIPAMENTO pelo Eng. Manuel Machado da Empresa Engecon de Poços de Caldas
- 4 LICITAÇÕES SEM APRESENTAÇÃO DE PROPOSTAS
- APRESENTAÇÃO DE UMA PROPOSTA DA EMIC pelo Eng. Antonio Rodrigues Gallego







# RECEPTION, CRUSHING AND PROCESSING OF AGGREGATES

- Preparação dos Agregados
- Britagem e Classificação





CANICA JAQUES

2008 8 15

# RECEPTION, CRUSHING AND PROCESSING OF AGGREGATES



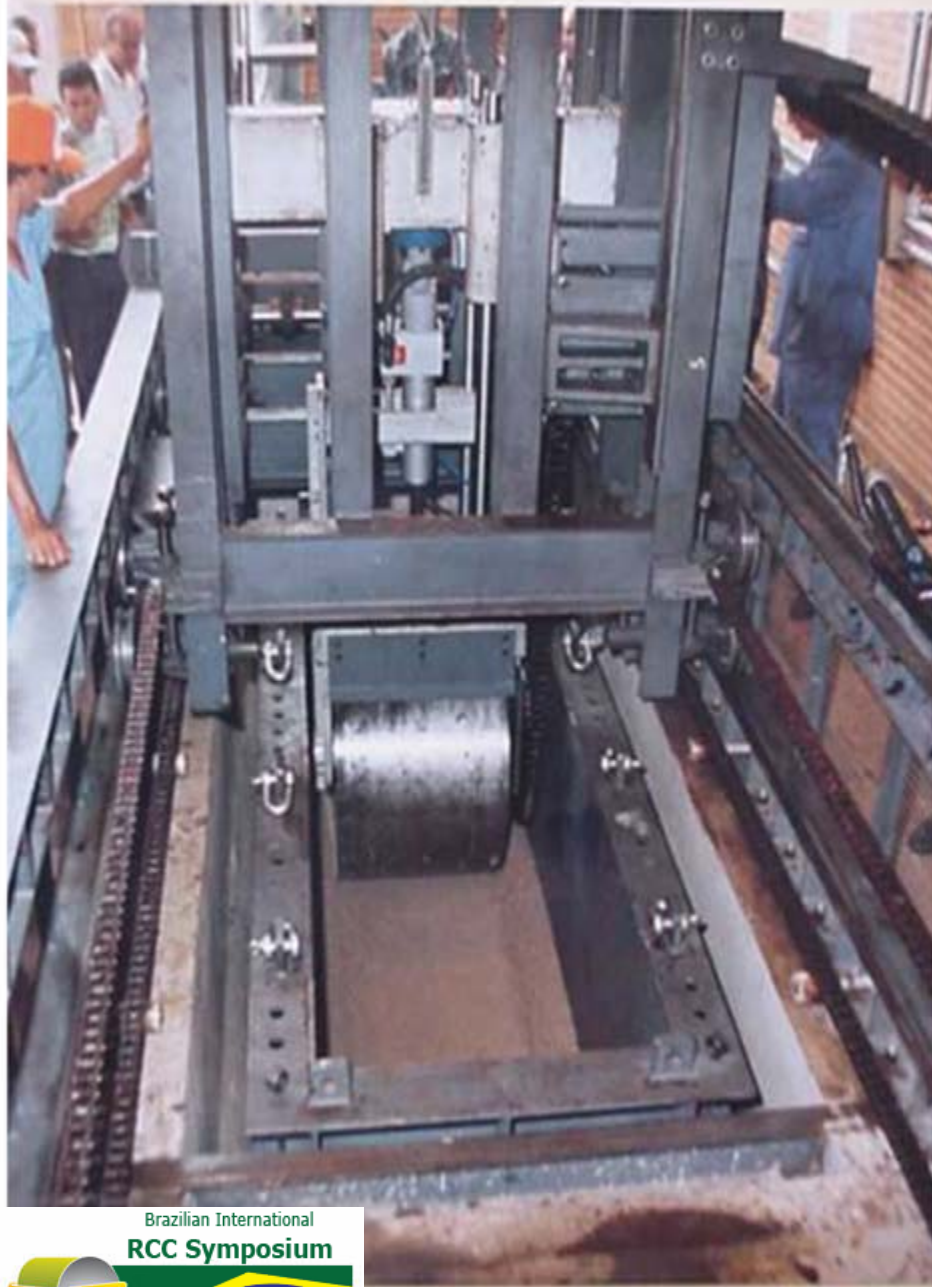
# RECEPTION, CRUSHING AND PROCESSING OF AGGREGATES

- Preparação dos Agregados
- Classificação e Rebritagem









Brazilian International  
RCC Symposium



IBRACON/RCC/2008









# Salão Antônio Rodrigues Gallego



# FRESH RCC PROPERTIES



# HERMIDA GERMAN

- **ENERGIA ULTRASONICA  
NUEVA TECNOLOGIA PARA EL  
ESTUDIO DEL CONCRETO  
COMPACTADO CON RODILLO  
EXPERIENCIA MIEL I.  
(COLOMBIA)**

# FABRICACION DE PROBETAS

## SISTEMAS DE IMPACTO



**Martillo neumático**



HERMIDA GERMAN



# FABRICACION DE PROBETAS

SISTEMAS DE IMPACTO

SISTEMAS VIBRACION (Mesa Vibratoria)



HERMIDA GERMAN

Brazilian International  
RCC Symposium



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# SISTEMAS DE VIBROCOMPACTACION

## VIBROCOMPACTADOR IET 05



- Frecuencia y amplitud variables.
- Es posible fabricar distintos tipos de probetas, (cilíndricas, troncocónicas, viguetas, etc).
- Elabora las probetas en una sola capa reproduciendo la distribución vertical de densidades obtenida en campo.

# Fresh Concrete Properties



# Unit Weight & Cannon Time

RCC

Quality Control

Fresh Concrete  
Cannon Time





# UNIT WEIGHT & WATER w CONTENT

## RCC Quality Control

Fresh Concrete

DMA

Dispositivo Medidor de Água

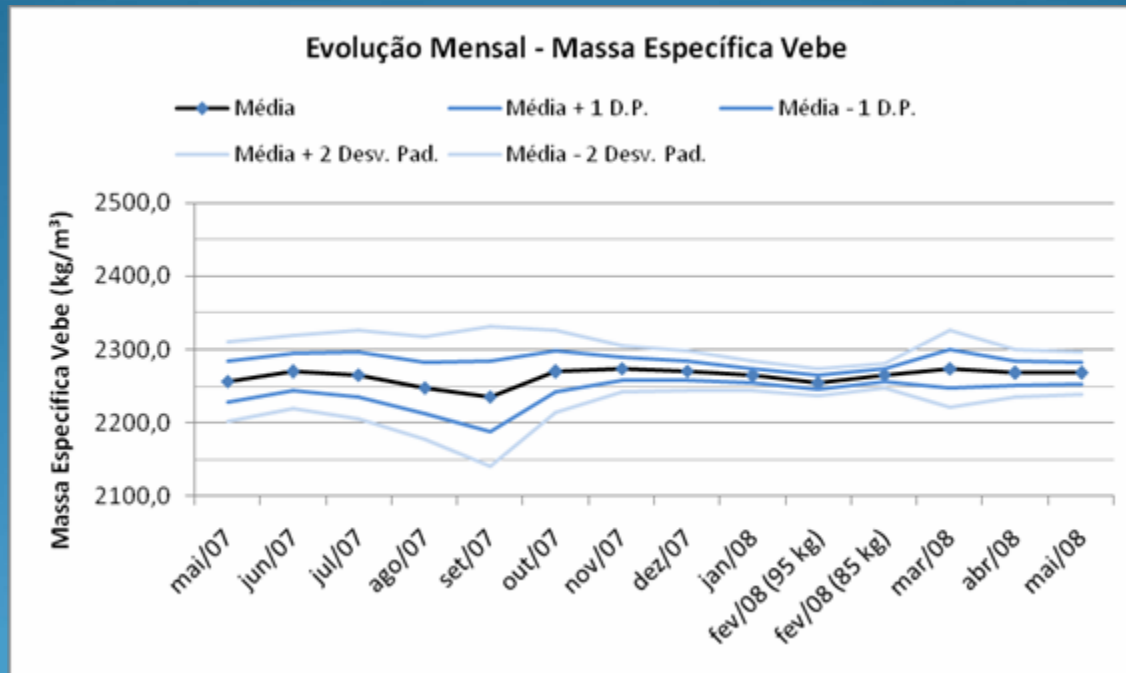








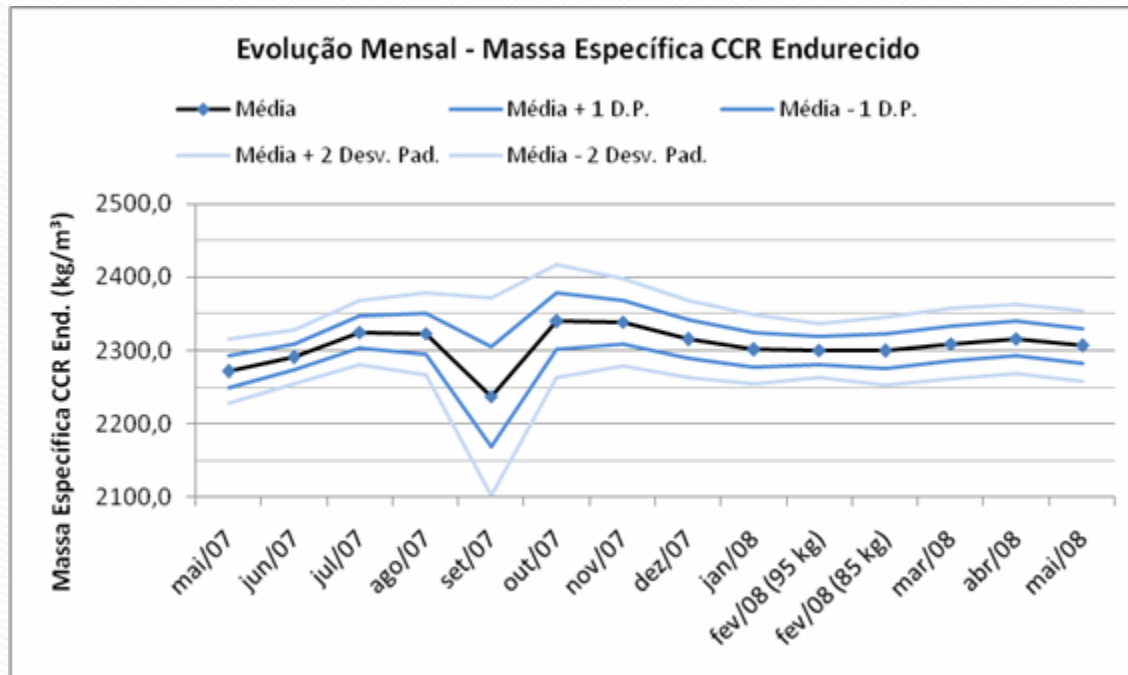
# UNIT WEIGHT MASSA ESPECÍFICA FRESH CONCRETE -VEBE



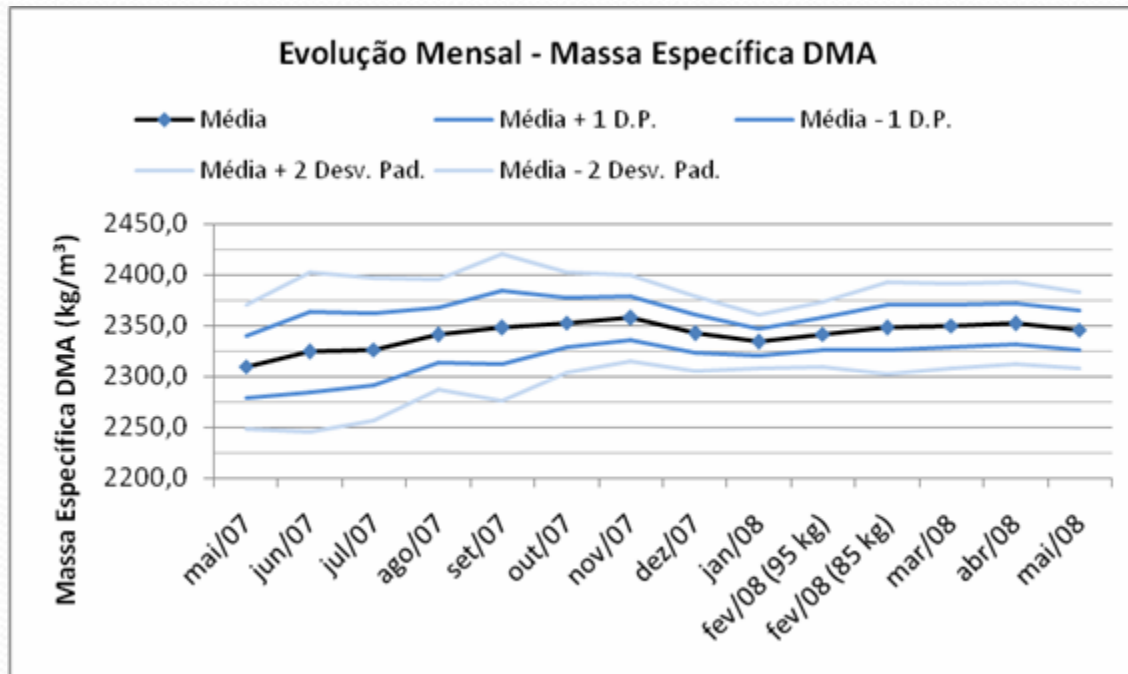
# SPECIFIC GRAVITY

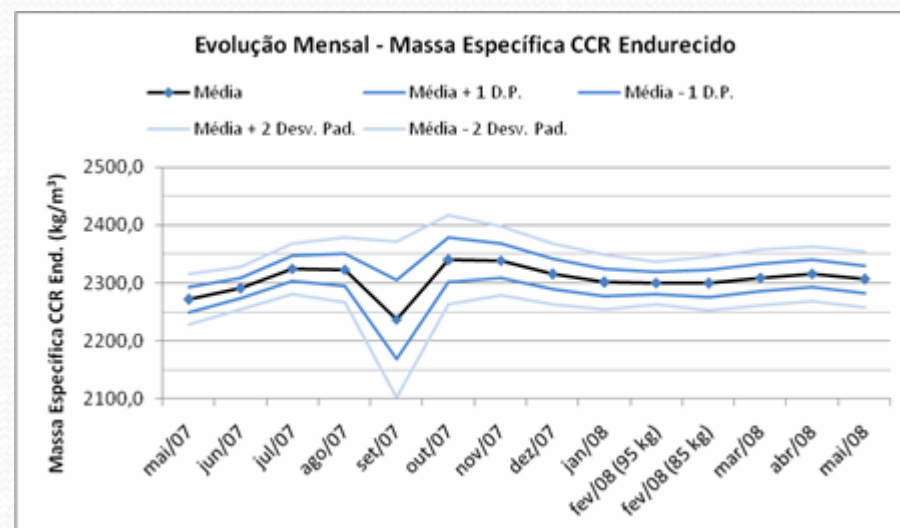
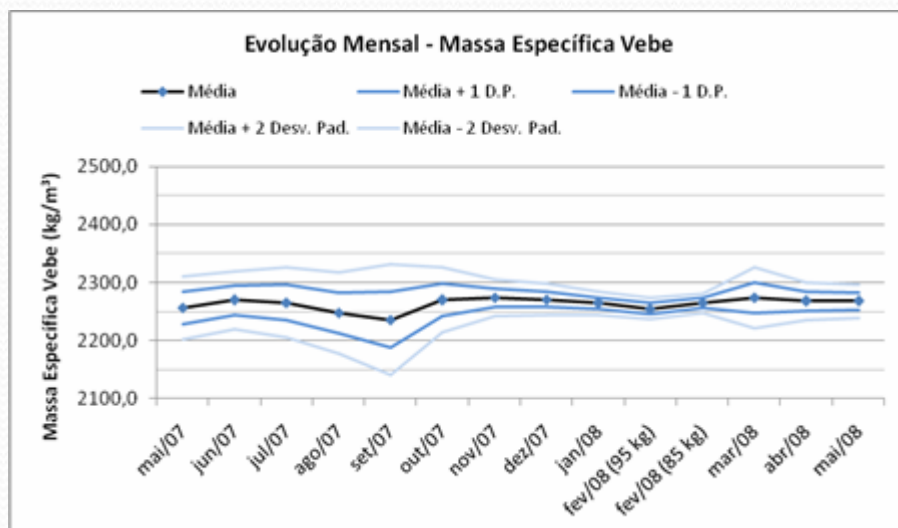
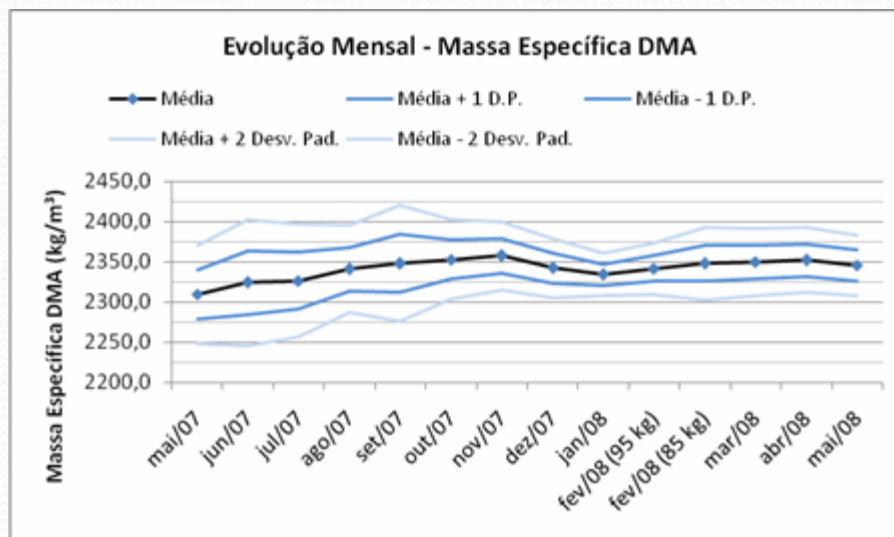
# MASSA ESPECÍFICA

# HARDENED CONCRETE



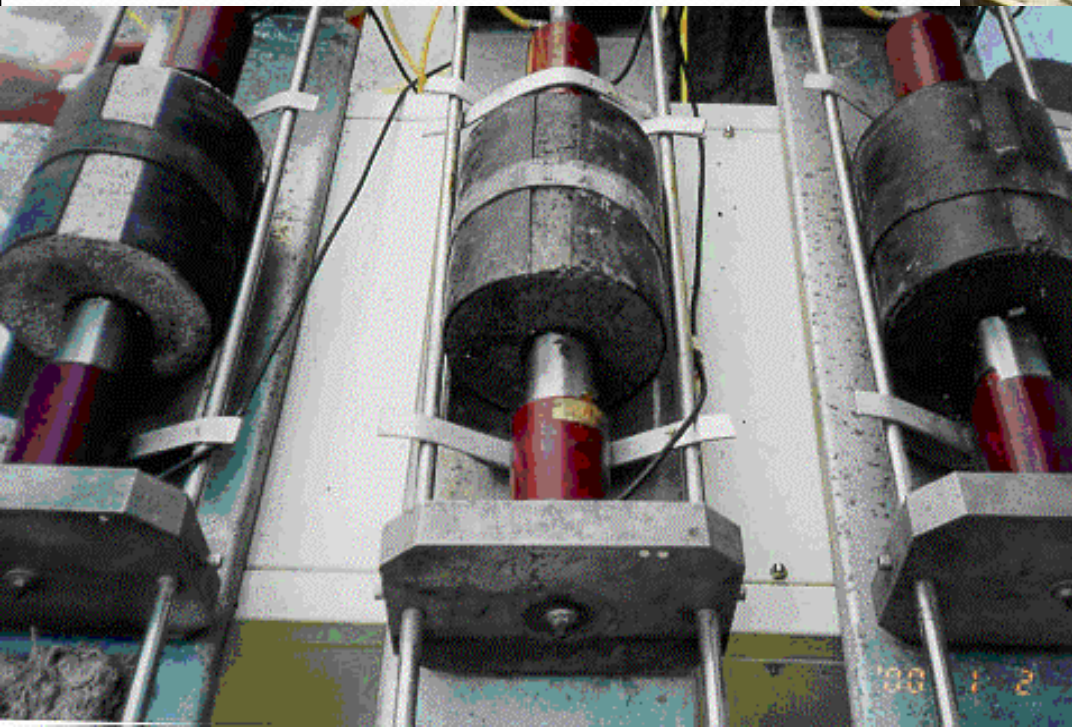
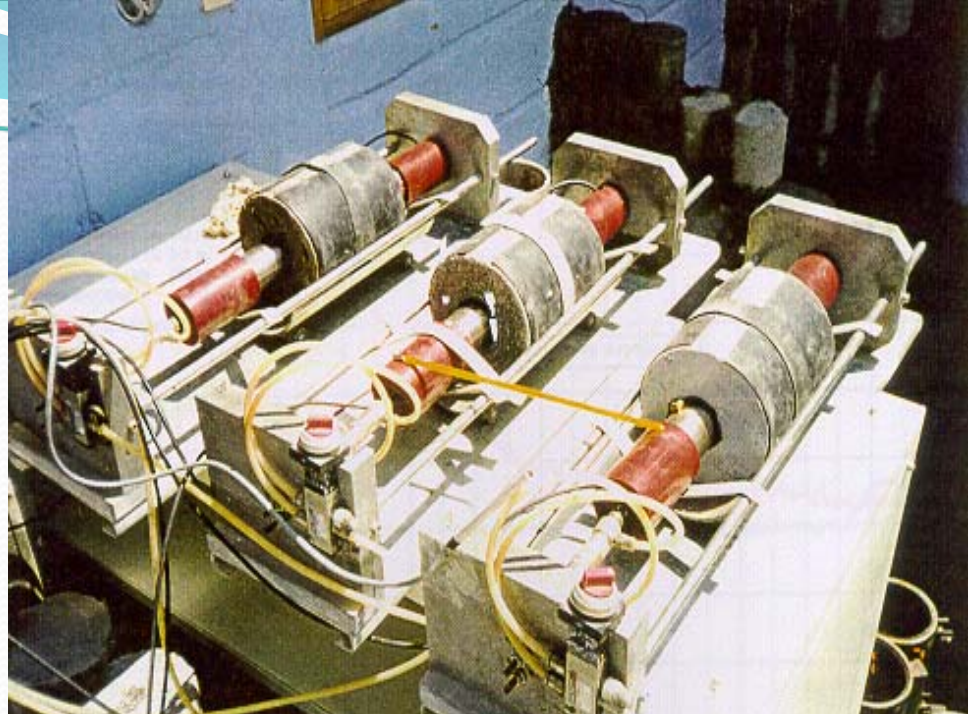
# UNIT WEIGHT DMA





# Setting Time

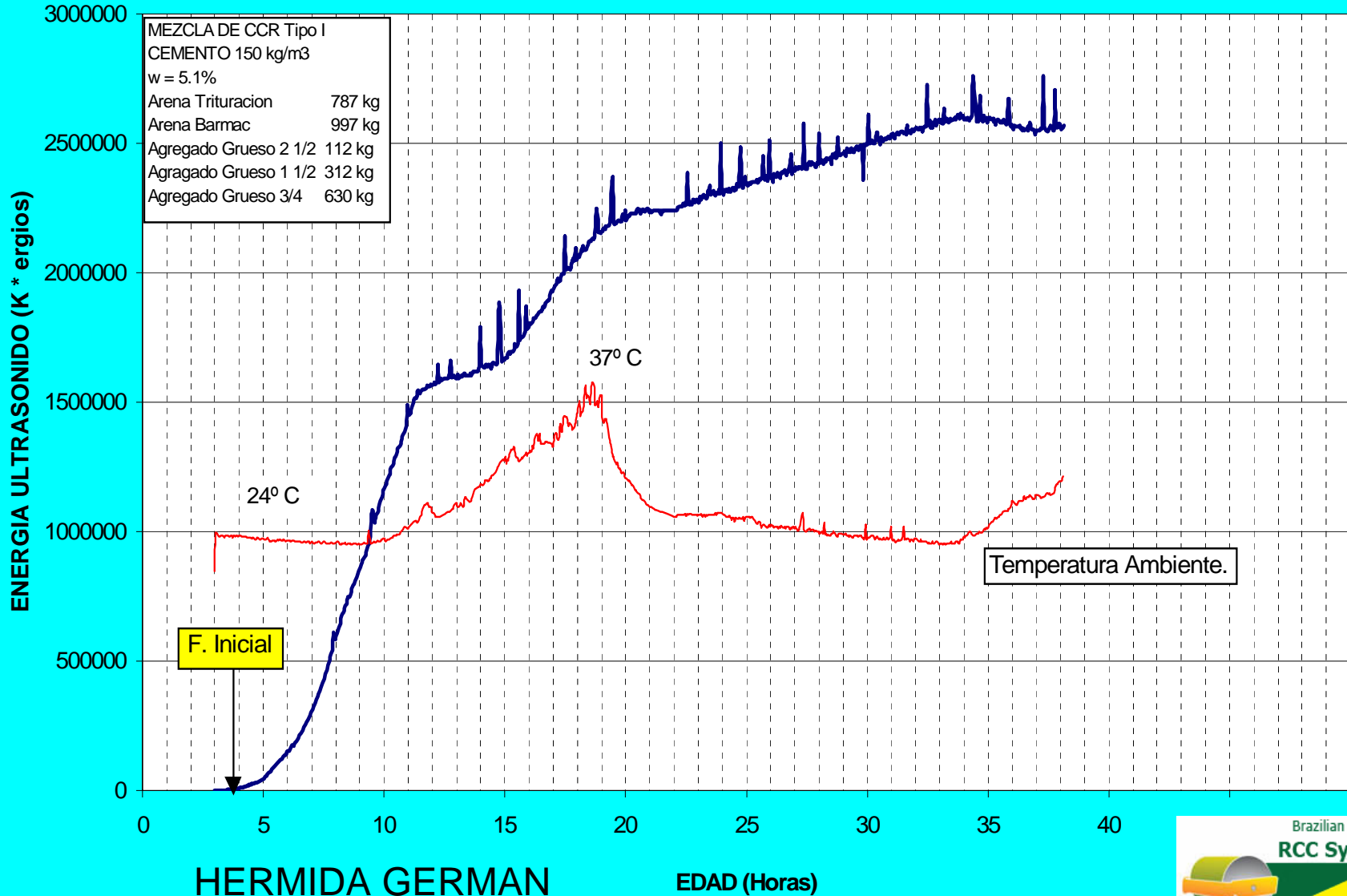
(Mezcla Tipo I- Miel I)



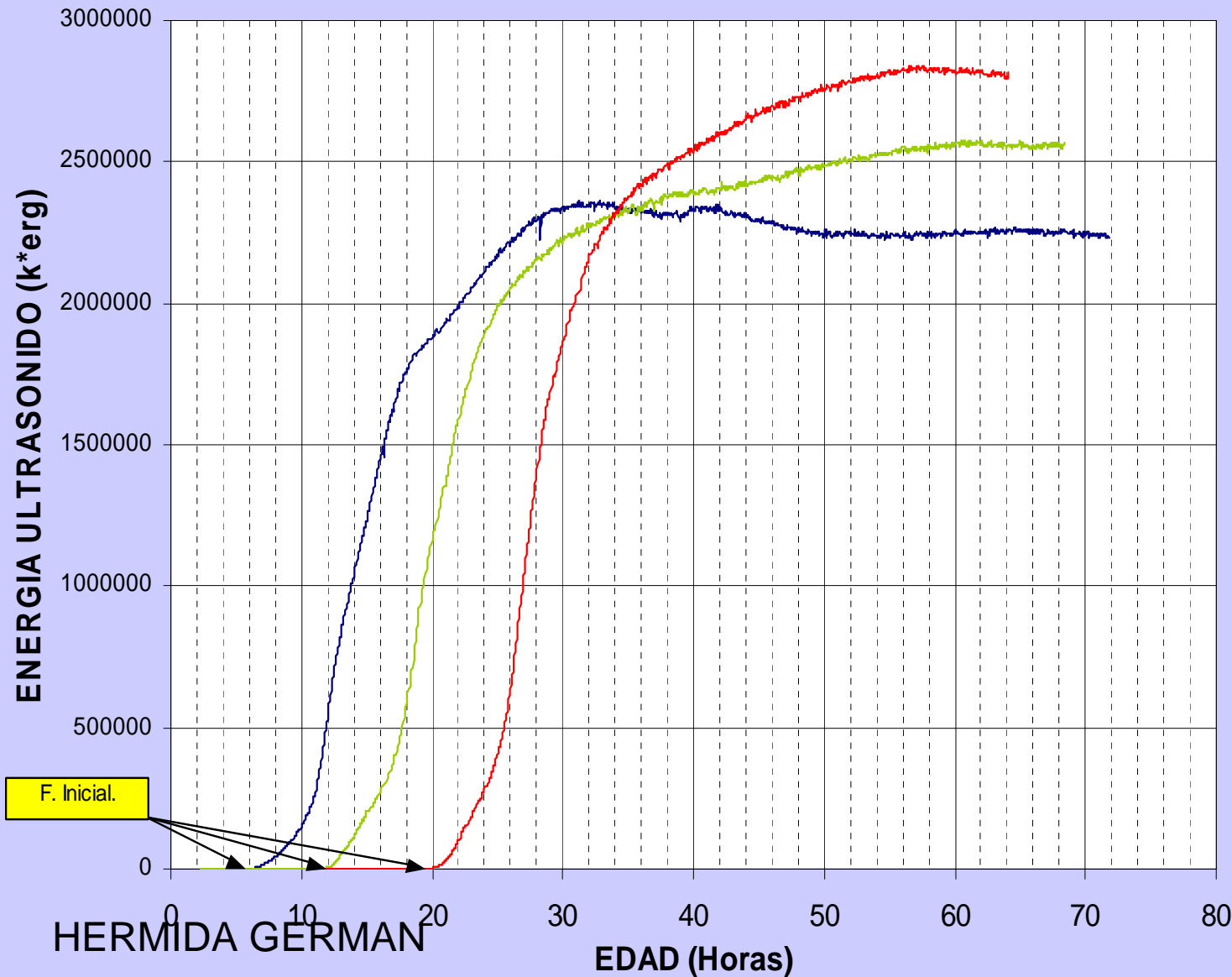
HERMIDA GERMAN

# ENERGIA ULTRASONICA CONDICIONES MAS FAVORABLES DE TEMPERATURA EXTERNA PARA EL FRAGUADO INICIAL- CCR (MEZCLA TIPO I)

TESTIGO (ENSAYO M025 A LA INTEMPERIE) 00-02-26 HR 80%



# ENERGIA ULTRASONICA MIEL I (CCR Tipo I) ENSAYO M015 (00-01-20)



F. Inicial.

HERMIDA GERMAN

EDAD (Horas)

— Testigo

— CCR (w=4.5%) 0.7% Aditivo

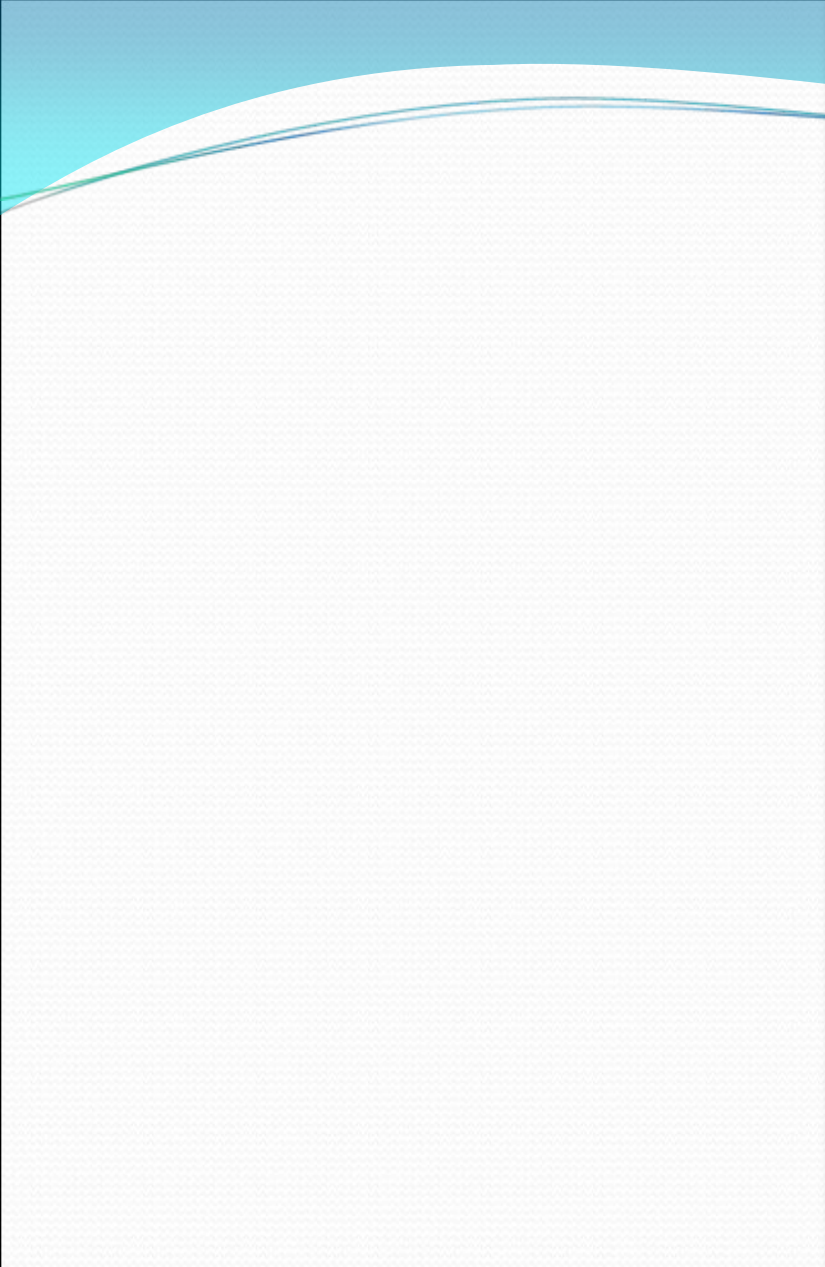
— CCR (w=4.5%) 1.0% Aditivo





# PERMEABILITY OF FRESH RCC





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**RCC Symposium**



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# COMPRESSIVE STRENGTH

# LOADING MACHINES



## CONSIDERATION OF OPTIMUM CEMENT CONTENT FOR MASS CONCRETE A Memorandum by Roy W. Carlson, January 1981

- The principal cause of cracking in massive concrete is the temperature change originating from the chemical action of the cement combining with water. If the concrete were free to expand or contract with temperature change, there would be no cracking. But there is nearly always some re-straint either from rigid foundations or from one part of the structure changing in temperature more than another. It is almost axiomatic that the higher the temperature rise during hydration, the greater will be the temperature differences and the higher the temperature stresses.



- It is only the temperature rise above a safe or tolerable value which causes serious cracking. This tolerable temperature is a few degrees above the "yearly average" or final temperature. A small increase in cement content above that which will cause the temperature to rise to the tolerable value can cause a large increase in the tendency to crack. In a typical example, an increase of 10 percent in cement content causes the amount of internal temperature rise above the safe value to increase by 20 to 30 percent. Conversely, A SMALL REDUCTION IN CEMENT CONTENT CAN CAUSE A LARGE REDUCTION IN THE TENDENCY TO CRACK.

# Realistic Approach for minus and plus correction factors

Factors	Coefficient (%)	Operation	Discrimination
Shape of the structure	3	+	A small plus correction should be applied because of the shape of the structure being more favorable than that of the cylinders. If the test cylinders were to have a length-diameter ratio of 1.5 instead of 2.0, they would more nearly simulate the structure and they would be 3 percent stronger according to ASTH. This would be a plus correction of 3 percent
Relaxation of overstressed regions	10	+	A plus correction of at least 10 percent should be applied to allow for relaxation of overstressed regions. In the case of an arch dam, model tests show the strength of the arch to be double that indicated by comparing the strength of job cylinders with the maximum design stress. In the case of a buttress dam, a correction factor of 10 percent would be conservative
Compression tests	5	+	A plus correction should be made because the compression tests do not reflect the true maximum stress in the test cylinder. When strains are measured on opposite sides of a cylinder being tested, there is always a difference, sometimes as much as 50 percent. Therefore, the ultimate stress in the cylinder is higher than the reported average. Since it is the maximum stress which is considered in the structure, it should be maximum stress in the test cylinders also. This would justify a plus correction of at least 5 percent

# Realistic Approach for minus and plus correction factors

Factors	Coefficient (%)	Operation	Discrimination
Wet-screening	20	-	The wet-screening correction (20 percent for Itaipu) is determined by test and most certainly should be applied without change
Variation in test cylinders	5	-	The minus correction for variation in test cylinders has been taken as 15 percent, which is much too high. The strength of a massive dam is not determined by the weakest part, but more nearly by the average strength. This correction should be not over 5 percent
Loss in strength due to sustained loading	5	-	The minus correction of 5 percent for loss in strength due to sustained loading is higher than found by long-time tests, but tolerable

# NÍVEIS DE CONTROLE DE RESISTÊNCIA



# TRANSIÇÕES



Tamanho do Cilindro pol. (mm.)	Resistência Relativa (%)	Tamanho do Cilindro pol. (mm.)	Resistência Relativa (%)
2" x 4" (5 x 10)	109	12" x 24" (30 x 60)	91
3" x 6" (7,5 x 15)	106	18" x 36" (45 x 90)	86
6" x 12" (15 x 30)	100	24" x 48" (60 x 120)	84
8" x 16" (20 x 40)	96	36" x 72" (90 x 180)	82

**Tabela 5.2.1.3- Efeito do Tamanho do Corpo de Prova na Resistência à Compressão Indicada do Concreto**

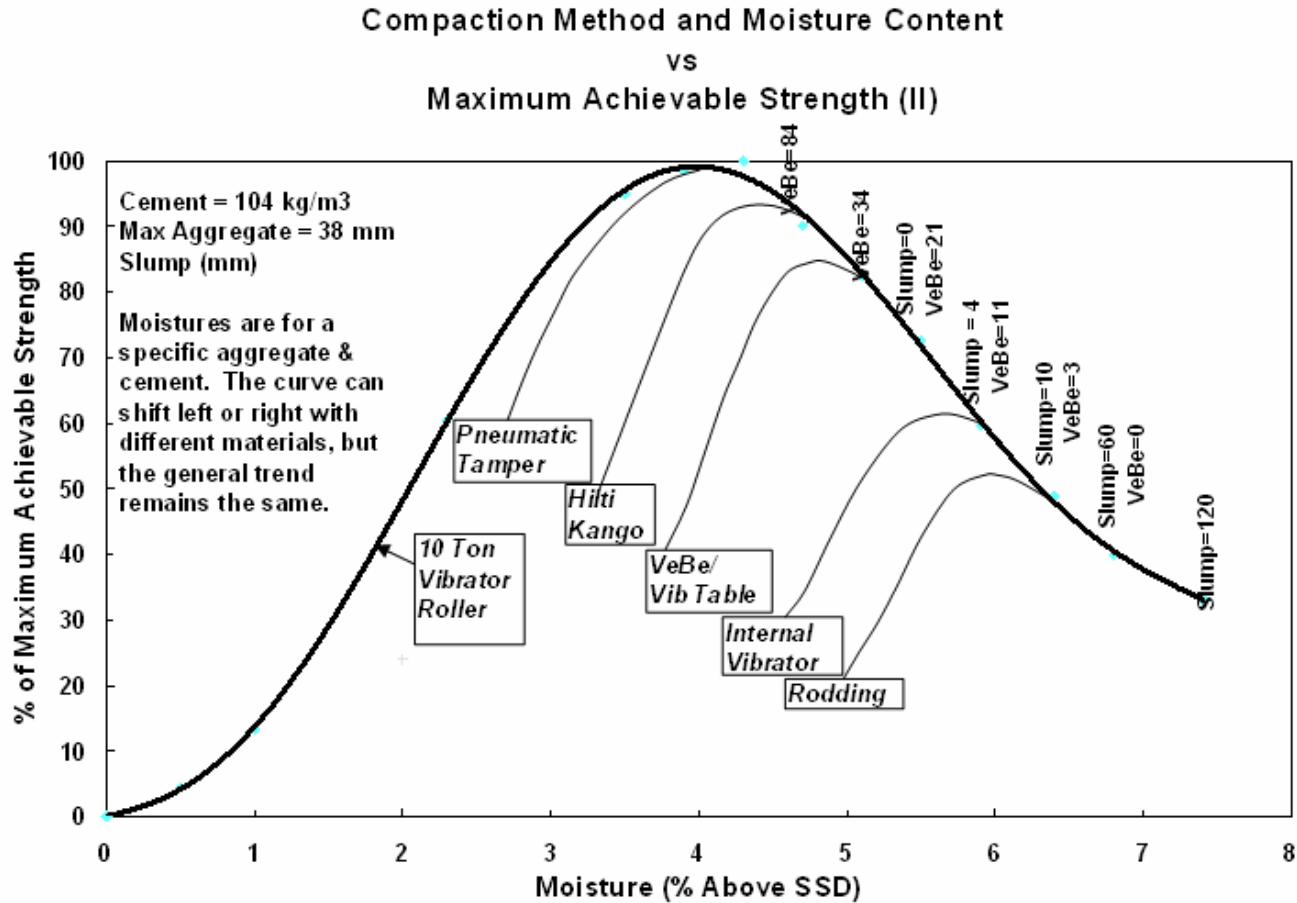
**Jerome M. Raphael - Mass Concrete in Dams**  
(ACI - SP 55 - pág. 143)



Figura 5.2.1.2 - Efeito do Tamanho do Cilindro na Resistência à Compressão do Concreto  
 Concrete Manual

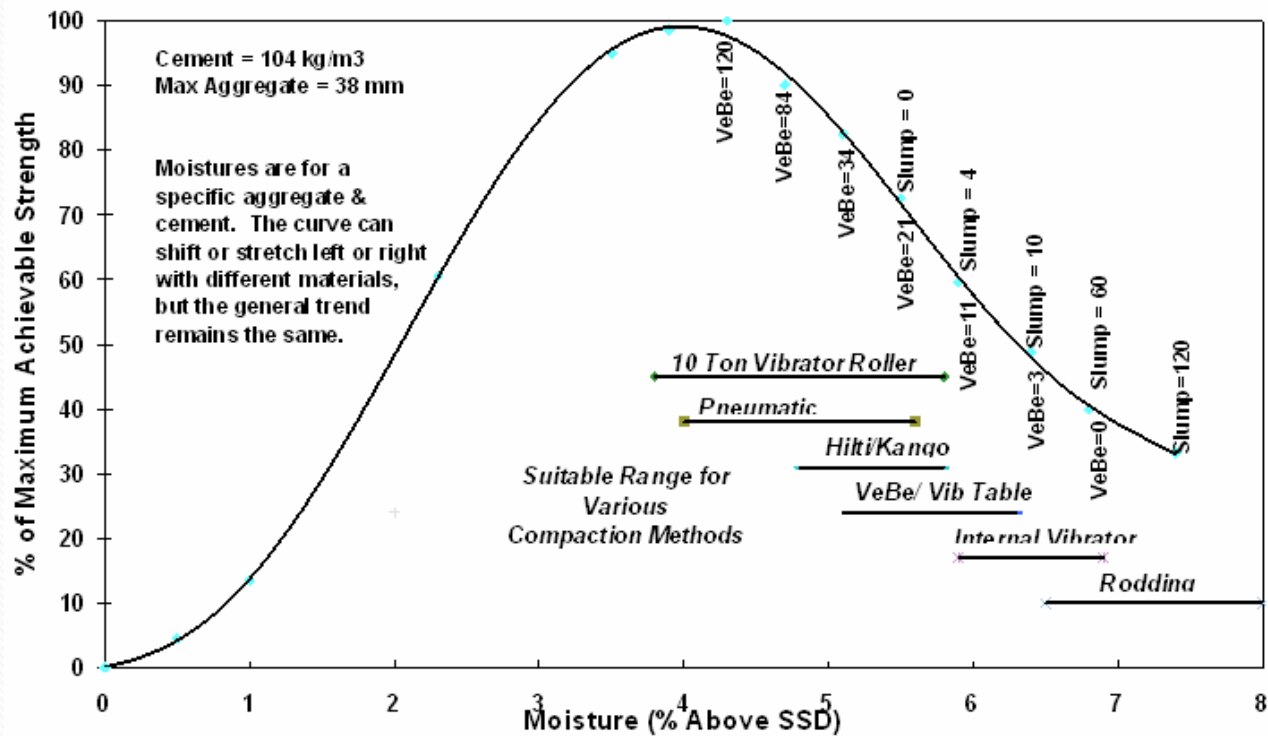
# MECHANICAL PROPERTIES

## Appropriate Laboratory Compaction Methods for Different Types of Roller Compacted Concrete (RCC)



# MECHANICAL PROPERTIES

Lab Compaction Method and Moisture Content  
vs  
Maximum Achievable Strength (I)





# MECHANICAL PROPERTIES

MIX	MODIFIED VeBe		PNEUMATIC TAMPER		10 TON ROLLER	
	Wet Density (Kg/m <sup>3</sup> )	No. of Tests	Wet Density (Kg/m <sup>3</sup> )	No. of Tests	Wet Density (Kg/m <sup>3</sup> )	No. of Tests
47 + 19	2340	29	2456	221	-	-
104 + 00	2316	11	2451	228	-	-
104 + 47	2308	24	2444	228	-	-
187 + 80	2353	17	2465	183	-	-
<b>Total No. of Tests</b>	-	81	-	860	-	1105
<b>Weighted Avg. Density</b>	2331	-	2452	-	2451	-

# MECHANICAL PROPERTIES

MIX C + F (Kg/m <sup>3</sup> )	VeBe TIME (Sec)	MIX WATER (SSD) (%)	TOTAL NUMBER of SAMPLES	COMPRESSION		SPLIT TENSION		MODULUS of ELASTICITY		RATIO (%) VeBe/Tamper		
				VeBe (MPa)	Tamper (MPa)	VeBe (MPa)	Tamper (MPa)	VeBe (GPa)	Tamper (GPa)	Compression	Tension	Modulus
47 + 19 (W)	120+	3.5 %	55	11.1 <sup>2</sup>	18.0 <sup>2</sup>	-	-	-	-	62 %	-	-
104 + 00 (W)	120+	3.6 %	53	12.9 <sup>2</sup>	26.0 <sup>2</sup>	-	-	-	-	50 %	-	-
104 + 47 (W)	45 <sup>1</sup>	3.6 %	53	22.8 <sup>2</sup>	28.6 <sup>2</sup>	-	-	-	-	78 %	-	-
187 + 80 (W)	35 <sup>1</sup>	4.5 %	46	34.1 <sup>2</sup>	39.9 <sup>2</sup>	-	-	-	-	85 %	-	-
196 + 77 (W)	15 <sup>1</sup>	5.6 %	14	31.7 <sup>2</sup>	31.6 <sup>2</sup>	-	-	-	-	100 %	-	-
100+00 (M1)	25-35	4.8%	12	4.3 <sup>3</sup>	4.6 <sup>3</sup>	0.6 <sup>3</sup>	0.6 <sup>3</sup>	10.5 <sup>3</sup>	7.7 <sup>3</sup>	93 %	100 %	136 %
100+00 (M1)	25-35	4.8%	12	6.8 <sup>4</sup>	6.9 <sup>4</sup>	0.8 <sup>4</sup>	0.9 <sup>4</sup>	20.5 <sup>4</sup>	19.2 <sup>4</sup>	99 %	89 %	107 %
125+00 (M1)	25-35	4.9%	6	6.6 <sup>3</sup>	6.9 <sup>3</sup>	0.8 <sup>3</sup>	0.8 <sup>3</sup>	15.0 <sup>3</sup>	14.7 <sup>3</sup>	96 %	100%	102 %
125+00 (M1)	25-35	4.9%	6	9.6 <sup>4</sup>	9.5 <sup>4</sup>	1.4 <sup>4</sup>	1.4 <sup>4</sup>	27.5 <sup>4</sup>	25.8 <sup>4</sup>	101 %	100 %	107 %

<sup>1</sup> Approximate average, based on a combination of tests and observation.

<sup>2</sup> Average 365 day test results.

<sup>3</sup> Average 7 day test results.

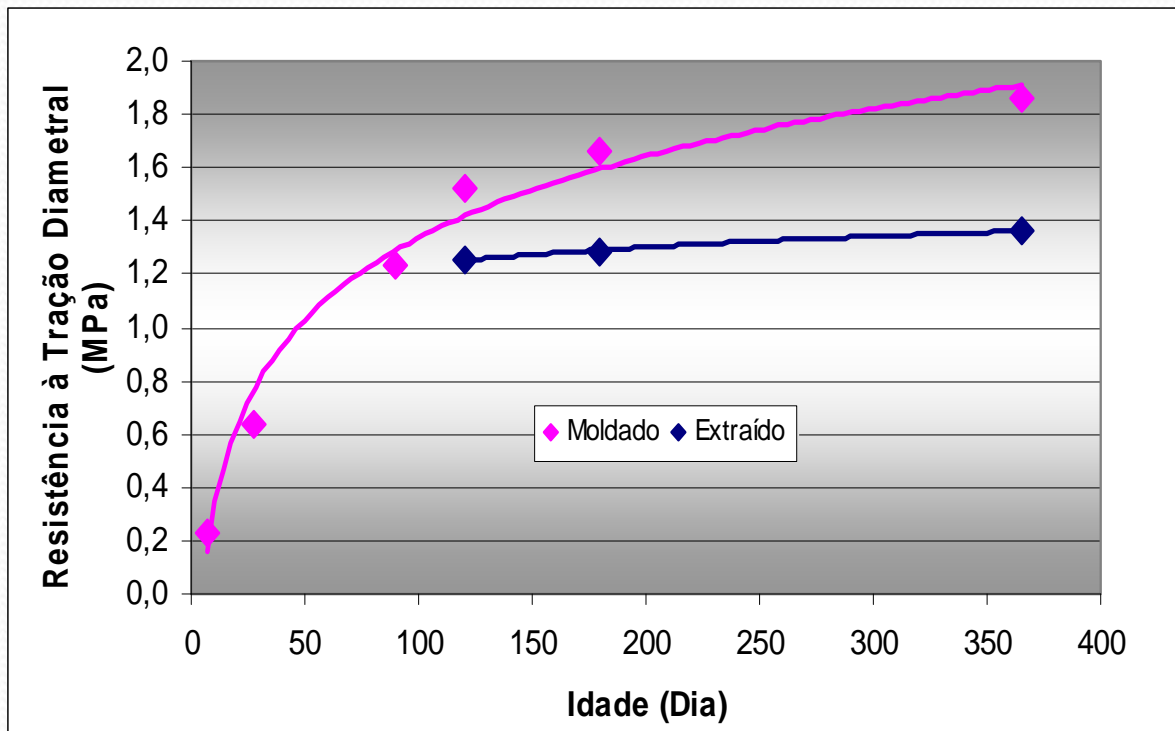
<sup>4</sup> Average 28 day test results.



# TENSILE STRENGTH

# Propriedades do Concreto Endurecido - Camada

- Resistência à Tração por Compressão Diametral

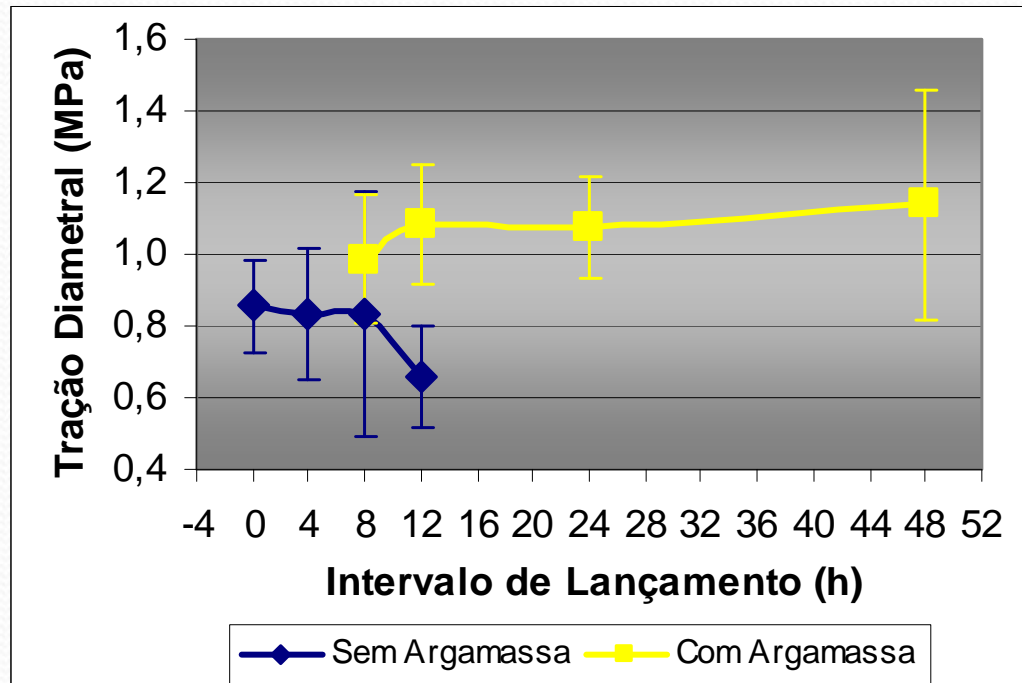


- $R_{TD}$  ▼ 18% a 30%.

Maurice Antoine Traboulsi

# Análise das Propriedades das Juntas

Resistência à Tração por Compressão Diametral  
(Considerações)

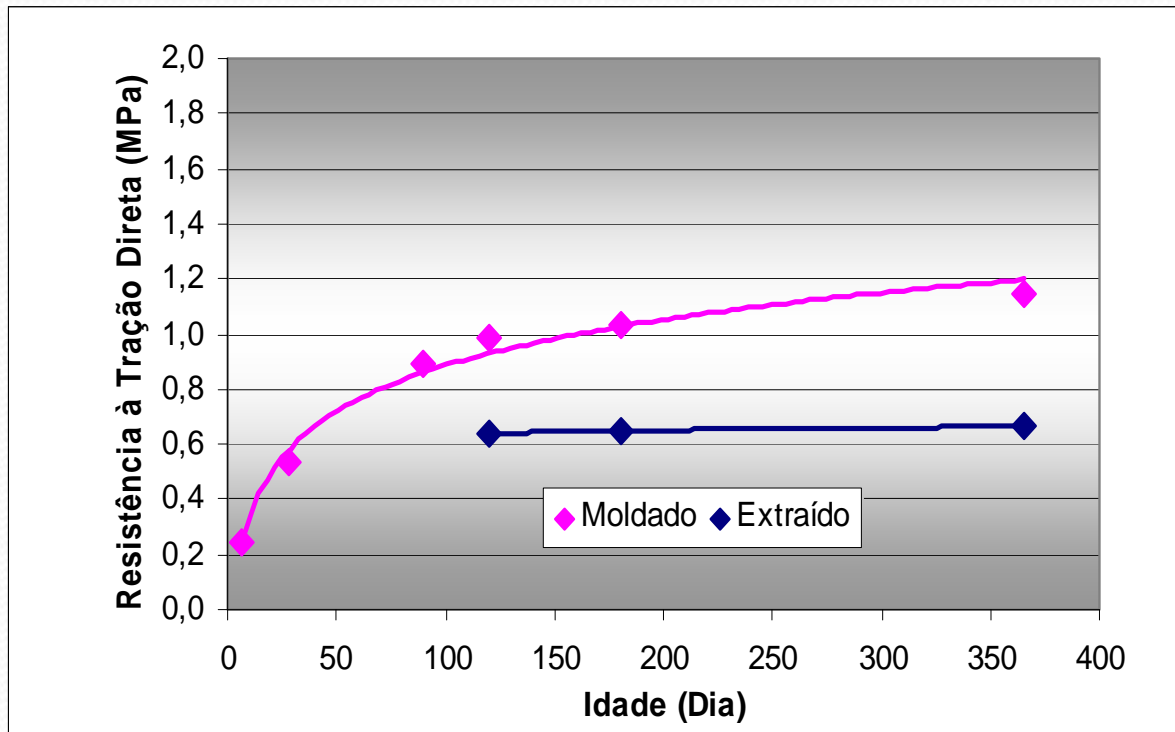


- s/arg ▼ (0h a 12h)
- c/arg ▲ (8h a 48h)

Maurice Antoine Traboulsi

# Propriedades do Concreto Endurecido - Camada

- Resistência à Tração Simples

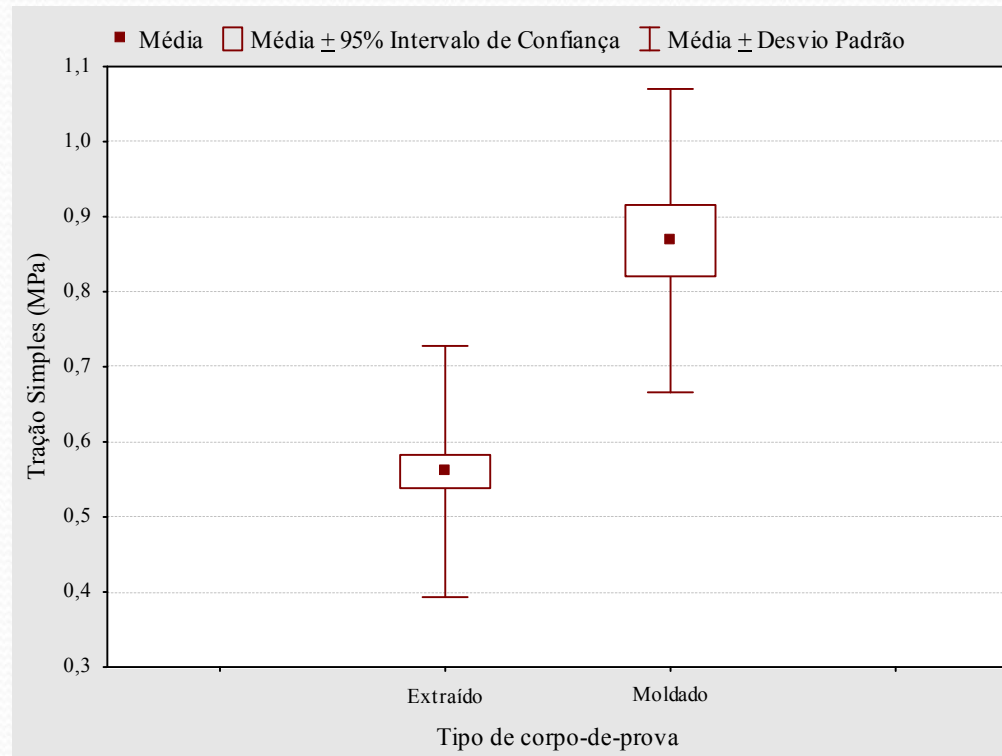


- Axialidade → ▲ CV (MARQUES FILHO, 2005).
- $R_T$  ▼ 35% a 42%

# Análise das Propriedades das

## Juntas

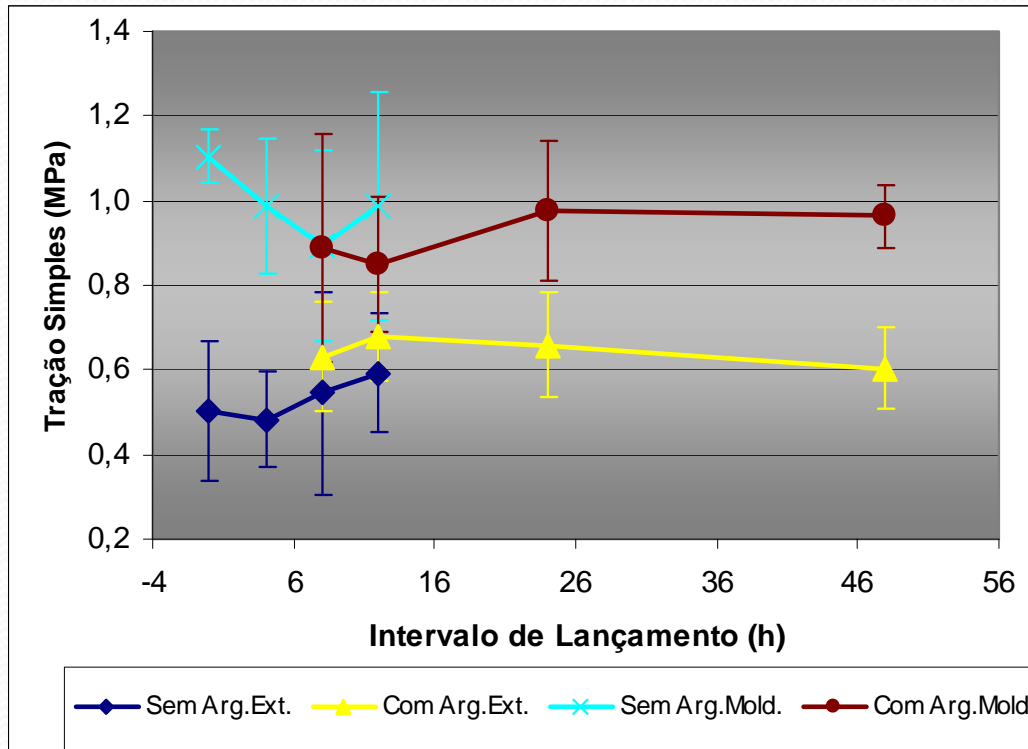
Resistência à Tração Simples (Tipo de Corpo-de-prova)



• Maurice Antoine Traboulsi

# Análise das Propriedades das Juntas

Resistência à Tração Simples (Considerações )



● CP's Moldados ▲ CP's Extraídos

● IL: NS

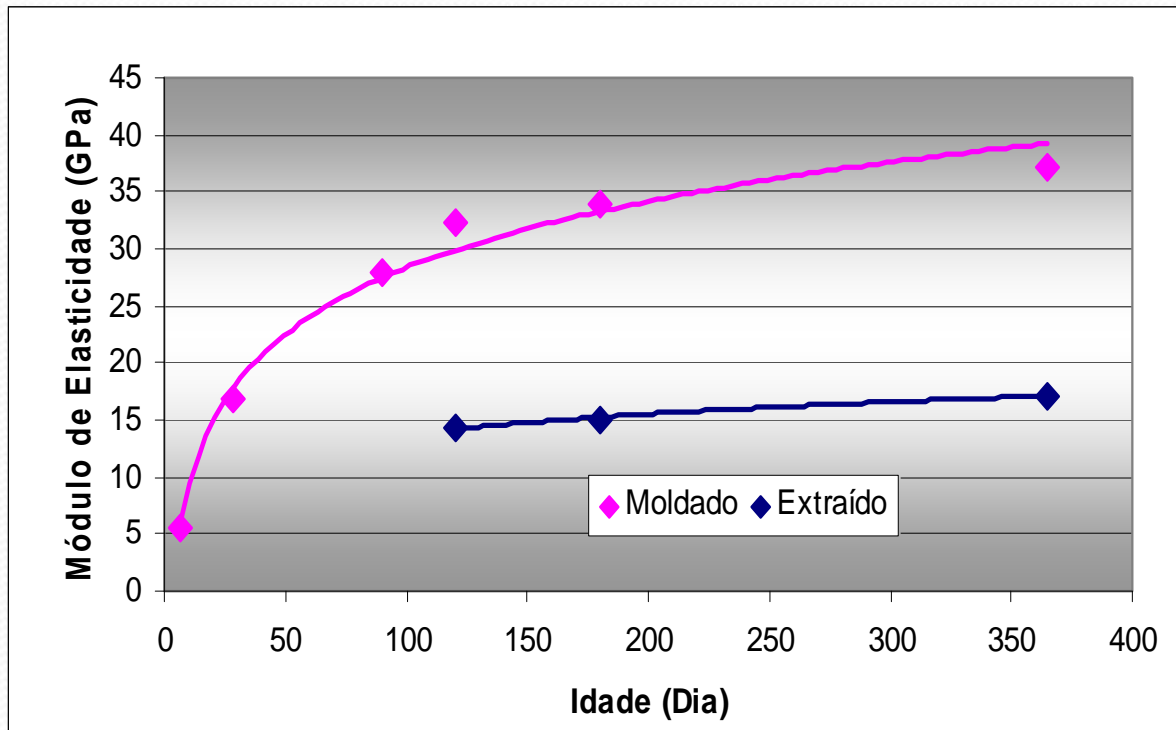
● Arg: S (Ext)

● Maurice Antoine Traboulsi



# Propriedades do Concreto

## Módulo de Elasticidade Endurecido - Camada



- Alta dispersão e queda dos resultados - **traumatismo** (MARQUES FILHO, 2005).
- $E \nabla$  50% e 56%.

# TENSILE STRENGTH OF LIFT JOINTS IN CONCRETE DAMS

Michael P. Forrest and John A. Bischoff

*URS Corporation*

- Of interest in the safety evaluation of arch dams is the condition and strength of the horizontal lift joints in the dam and their ability to carry tensile stresses under loadings acting on the dam. In particular, the lift joints must be able to withstand earthquake-induced cantilever tensile stresses, especially those acting on the upper portions of the central arch of the dam.
- One of the most important factors influencing the tensile strength of concrete lift joints relates to the methods used to prepare (clean and/or treat) the surfaces of the lift joints prior to placement of concrete on them. Modern dam construction procedures provide for the use of one or more lift joint surface preparation methods for new dam construction or repair of existing (old) dams.

- These methods include: (1) removal of loose particles and laitance by brushing or air/water jetting; (2) thorough moistening the previously placed concrete surface; and (3) wet sand blasting or high-pressure water jetting if the old concrete has significantly set; and (4) placement of mortar coats or bonding agents (e.g., epoxies) between the old and new concrete. Pre-wetting has been shown to have only small beneficial effects Wall and Shrive, 1988 (1).

TABLE 1. Average Tensile Bending Strength Reduction Factors Across Lift Joints

PLACEMENT ON UNTREATED SURFACE	References						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
▪ Young joint, laitance left in place	-	0.45	0.31	-	-	-	-
▪ Dry sand thrown on fresh concrete, then washed off	-	0.41	-	-	-	-	-
▪ Old dry joint	-	-	-	0.74	-	-	-
▪ Young joint, concrete dried out	-	0.78	-	-	-	-	-
▪ Old wet joint	-	-	-	0.83	-	-	-
▪ Laboratory-desiccated concrete	-	0.86	-	-	-	-	-
<b>PLACEMENT ON TREATED DRY CONCRETE: Joint Preparation Method</b>							
▪ Wire-brushed, hand compaction	0.55	0.57	-	-	-	-	-
▪ Wire-brushed, vibrated	0.75	-	-	-	-	-	-
▪ Dry sand-blasted	-	-	-	-	-	-	0.87
▪ Wire-brushed, dried concrete	-	0.76	-	-	-	-	-
▪ High-pressure jet, dried concrete	-	-	-	-	0.80	-	-
▪ Young dry joint with thick flowed mortar	-	-	-	0.88	-	-	-
▪ Young dry joint with thin broomed mortar	-	-	-	0.90	-	-	-
▪ Young dry joint with thin flowed mortar	-	-	-	0.86	-	-	-
▪ Young dry joint with thick broomed mortar	-	-	-	0.72	-	-	-
▪ Old dry joint with thick broomed mortar	-	-	-	0.78	-	-	-
▪ High pressure jet with mortar, dry joint	-	-	-	-	0.72	-	-
<b>PLACEMENT ON TREATED WET CONCRETE: Joint Preparation Method</b>							
▪ Air-water jet, hand compaction	0.66	-	-	-	-	-	-
▪ Air-water jet, vibrated	0.83	-	-	-	-	-	-
▪ Wet sandblasting, laitance removed	-	0.53	0.71	-	-	-	-
▪ Wet sandblasting, aggregate exposed	-	0.78	-	-	-	-	-
▪ High-pressure jet	-	-	-	-	0.75	0.73	-
▪ Air-water jet, young joint with thick broomed mortar	-	-	-	0.96	-	-	-
▪ Air-water jet, young joint with thick flowed mortar	-	-	-	0.64	-	-	-
▪ Air-water jet, young joint with thin broomed mortar	-	-	-	0.85	-	-	-
▪ Air-water jet, young joint with thin flowed mortar	-	-	-	0.94	-	-	-
▪ Air-water jet, old joint with thick broomed mortar	-	-	-	0.94	-	0.92	-
▪ High pressure jet, with mortar	-	-	-	-	0.70	-	-

REFERENCES 1. Davis and Davis (1934)  
2. Waters (1954)

3. Tynes (1959)  
4. US Army Corps of Engineers (1963)

5. Tynes & McCleese (1973)  
6. Houghton and Hall (1972)

7. US Bureau of Reclamation, Tarbox, Dreher, and Carpenter (1979)

Q.82 – R6

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▪ Young joint, laitance left in place	-	0.45	0.31	-	-	-	-
▪ Dry sand thrown on fresh concrete, then washed off	-	0.41	-	-	-	-	-
▪ Old dry joint	-	-	-	0.74	-	-	-
▪ Young joint, concrete dried out	-	0.78	-	-	-	-	-
▪ Old wet joint	-	-	-	0.83	-	-	-
▪ Laboratory-desiccated concrete	-	0.86	-	-	-	-	-

**PLACEMENT ON TREATED DRY CONCRETE: Joint Preparation Method**

▪ Wire-brushed, hand compaction	0.55	0.57	-	-	-	-	-
▪ Wire-brushed, vibrated	0.75	-	-	-	-	-	-
▪ Dry sand-blasted	-	-	-	-	-	-	0.87
▪ Wire-brushed, dried concrete	-	0.76	-	-	-	-	-
▪ High-pressure jet, dried concrete	-	-	-	-	0.80	-	-
▪ Young dry joint with thick flowed mortar	-	-	-	0.88	-	-	-
▪ Young dry joint with thin broomed mortar	-	-	-	0.90	-	-	-
▪ Young dry joint with thin flowed mortar	-	-	-	0.86	-	-	-
▪ Young dry joint with thick broomed mortar	-	-	-	0.72	-	-	-
▪ Old dry joint with thick broomed mortar	-	-	-	0.78	-	-	-
▪ High pressure jet with mortar, dry joint	-	-	-	-	0.72	-	-

Q.82 – R6

**PLACEMENT ON TREATED WET CONCRETE: Joint Preparation Method**

▪ Air-water jet, hand compaction	0.66	-	-	-	-	-	-
▪ Air-water jet, vibrated	0.83	-	-	-	-	-	-
▪ Wet sandblasting, laitance removed	-	0.53	0.71	-	-	-	-
▪ Wet sandblasting, aggregate exposed	-	0.78	-	-	-	-	-
▪ High-pressure jet	-	-	-	-	0.75	0.73	-
▪ Air-water jet, young joint with thick broomed mortar	-	-	-	0.96	-	-	-
▪ Air-water jet, young joint with thick flowed mortar	-	-	-	0.64	-	-	-
▪ Air-water jet, young joint with thin broomed mortar	-	-	-	0.85	-	-	-
▪ Air-water jet, young joint with thin flowed mortar	-	-	-	0.94	-	-	-
▪ Air-water jet, old joint with thick broomed mortar	-	-	-	0.94	-	0.92	-
▪ High pressure jet, with mortar	-	-	-	-	0.70	-	-

REFERENCES 1. Davis and Davis (1934)  
2. Waters (1954)

3. Tynes (1959)  
4. US Army Corps of Engineers (1963)

5. Tynes & McCleese (1973)  
6. Houghton and Hall (1972)

7. US Bureau of Reclamation, Tarbox, Dreher, and Carpenter (1979)

# MECHANICAL PROPERTIES

**TABELA 6.2** Relação entre Resistências à Tração Direta e por Compressão Diametral. Corpos-de-Prova Moldados

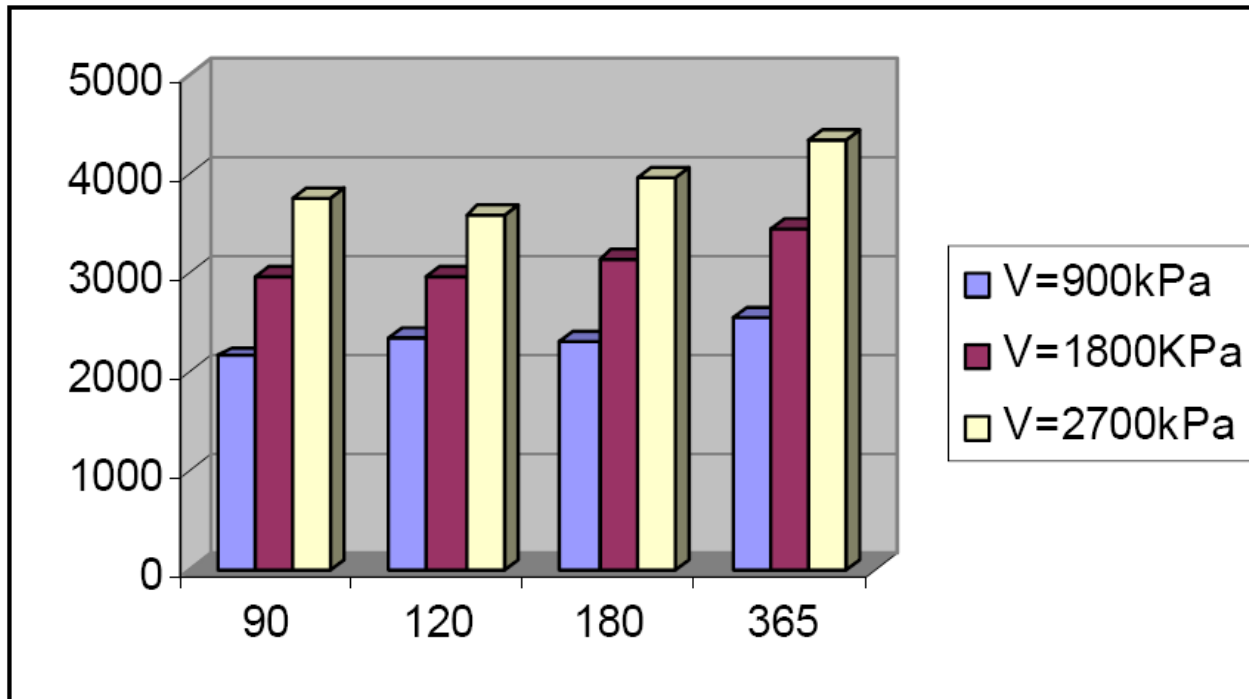
IDADE (dias)	RELAÇÃO RESISTÊNCIA À TRAÇÃO DIRETA/COMPRESSÃO DIAMETRAL
7	79%
28	65%
90	63%
120	68%
180	66%





**SHEAR**

# SHEAR



**RA 6.6** Comparação dos Valores de Esforços Resistentes ao Cisalhamento Obtidos das Correlações nas Várias Idades

# Resistência ao Cisalhamento de Camadas de CCR

José Marques Filho

COPEL

Vladimir Antonio Paulon

UNICAMP

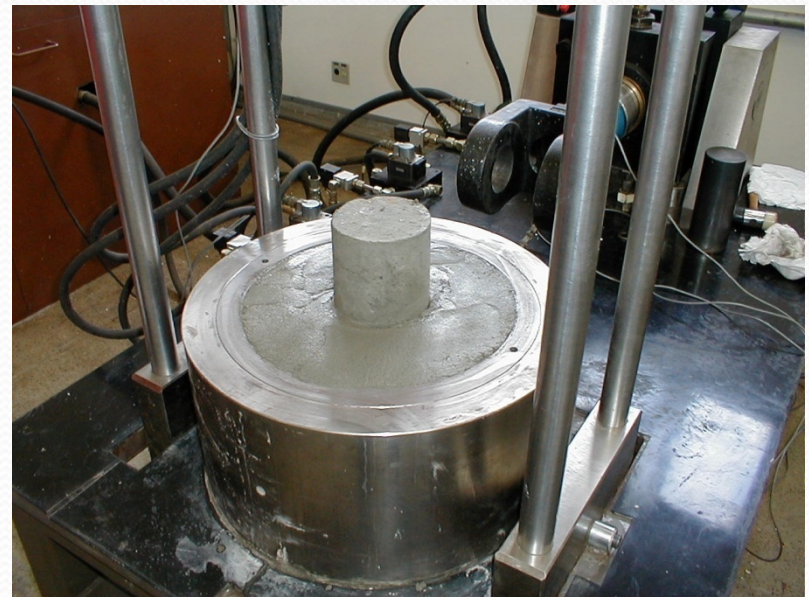
Denise C. C. Dal Molin

UFRGS

Maurice Antoine Traboulsi FURNAS



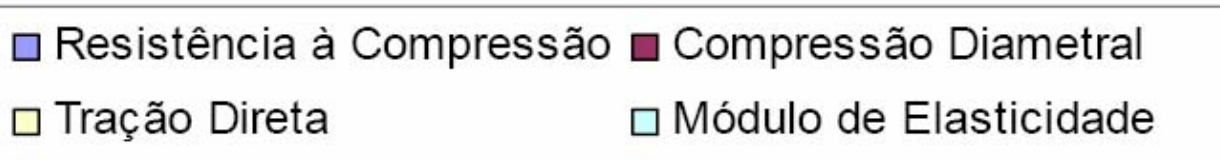
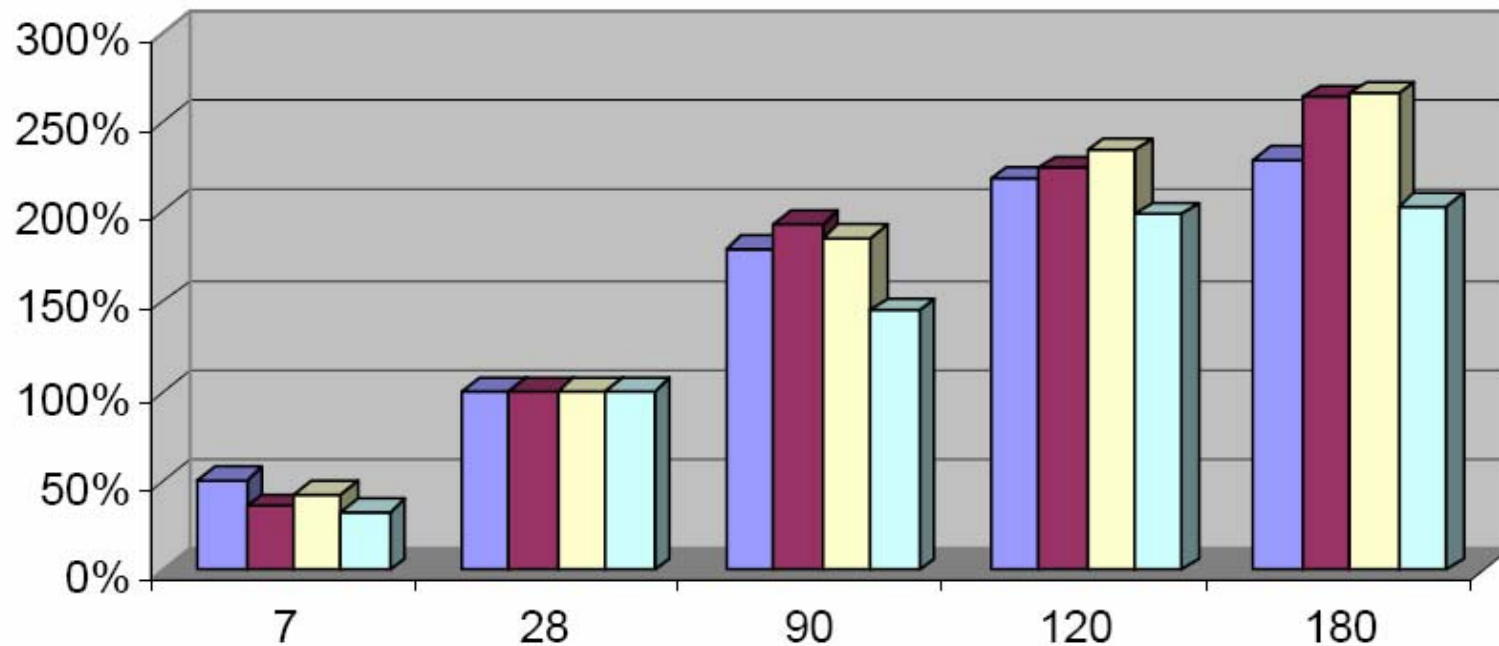
# Ensaio de Cisalhamento Direto



**TABELA 6.3** Relação entre Resistência à Tração e Resistência à Compressão para Corpos-de-Prova Moldados

IDADE	TRAÇÃO POR COMPRESSÃO DIAMETRAL	TRAÇÃO DIRETA
7	9,8%	7,7%
28	14,1%	9,2%
90	15,2%	9,5%
120	14,4%	9,9%
180	16,2%	10,7%

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**TABELA 6.7** Relação entre Resistências à Tração Direta e por Compressão Diametral para Testemunhos

IDADE (dias)	RELAÇÃO RESISTÊNCIA À TRAÇÃO DIRETA/COMPRESSÃO DIAMETRAL
120	60%
180	56%
365	48%

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**TABELA 6.8** Relação entre Resistência à Tração e Resistência à Compressão para Testemunhos

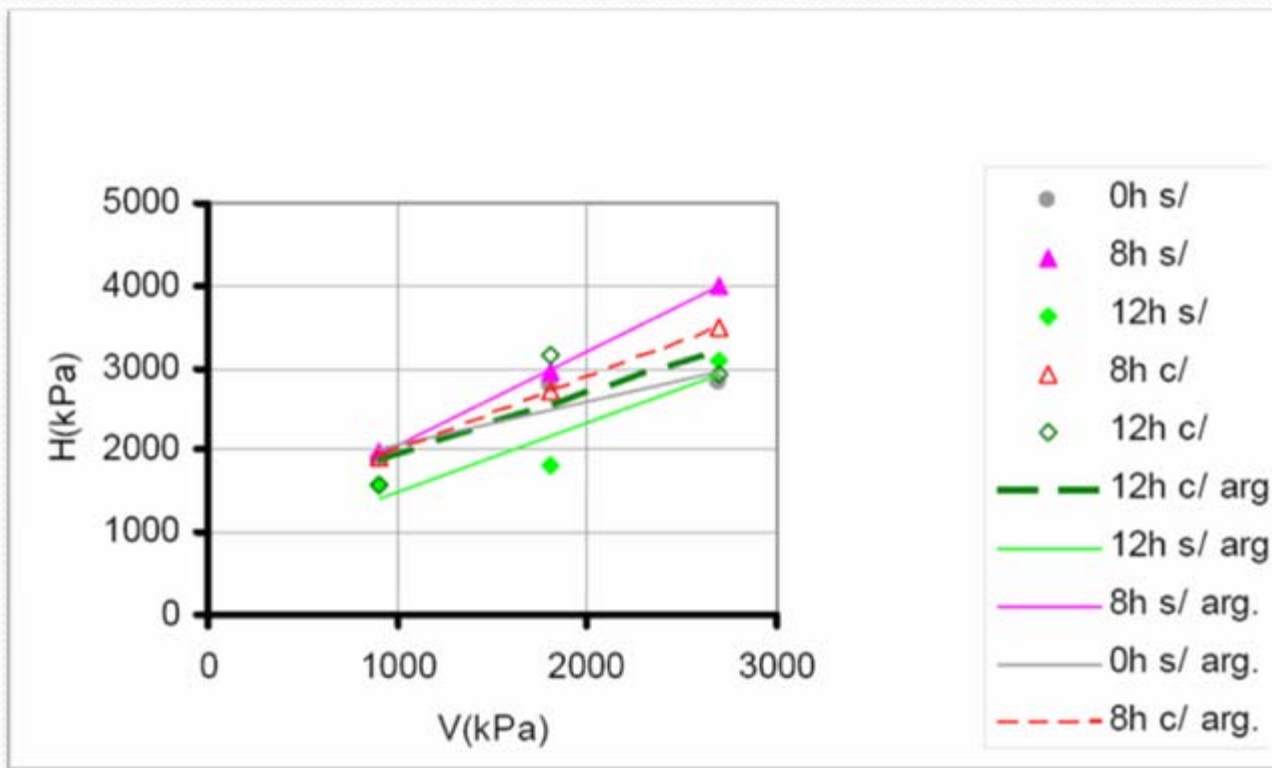
IDADE	TRAÇÃO POR COMPRESSÃO DIAMETRAL	TRAÇÃO DIRETA
120	18%	11%
180	14%	8%
365	11%	5%

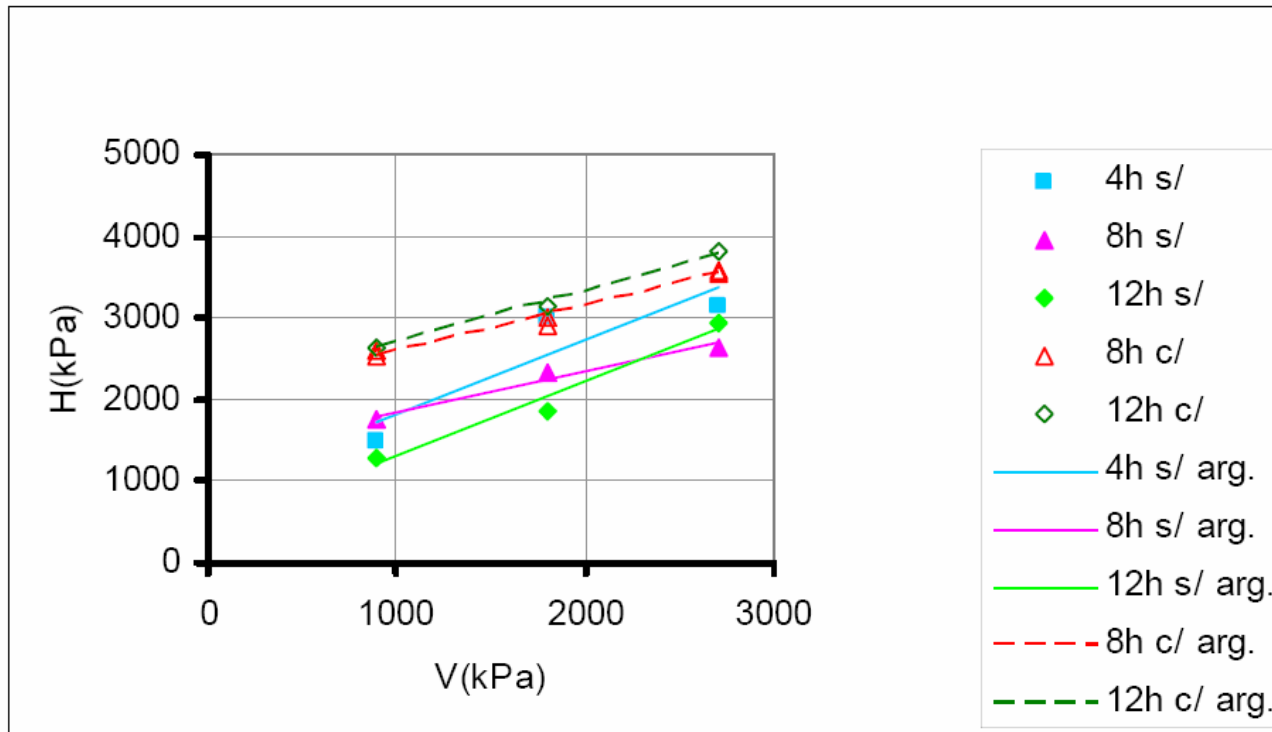


**ABELA 6.12** Parâmetros das Envoltórias de Resistência para a Análise da Envoltória de Resistência entre Camadas com Intervalo de Tempo Inferiores a 12h

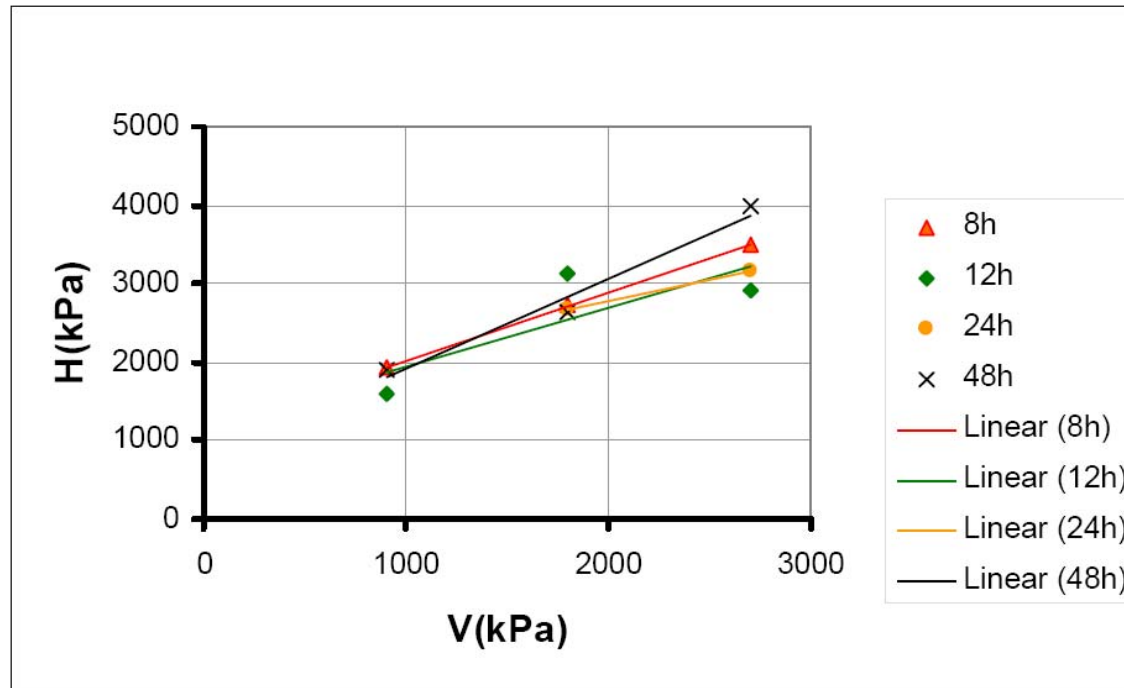
IDADE (dias)	LIMPEZA	TRAT.	25°C			45°C		
			COESÃO (kPa)	ÂNGULO ATRITO (graus)	R2	COESÃO (kPa)	ÂNGULO ATRITO (graus)	R2
120	Ar Compr	0h s/	1.555	27,5	0,7676	xx	xx	xx
		4h s/	xx	xx	xx	876	42,8	0,8169
		8h s/	934	48,6	0,9997	1.350	26,1	0,967
		12h s/	634	40,3	0,8669	378	42,6	0,9694
		8h c/	1.140	41,2	0,9999	2.029	29,2	0,9694
		12h c/	1.226	36,3	0,6222	2.042	32,8	0,9948
	Apicoam.	0h s/	1.008	38,5	0,7987	xx	xx	xx
		4h s/	1.041	33,8	0,9283	xx	xx	xx
		8h s/	xx	xx	xx	1.257	39,8	1
		8h c/	1.182	36,6	0,9946	1.514	41,4	1
		12h c/	902	47,8	0,9996	1257	52,4	0,9911

180	Ar Compr	0h s/	1.555	27,5	0,7676	xx	xx	xx
		4h s/	xx	xx	xx	1.014	39,7	0,9557
		8h s/	527	54,4	0,9878	1.229	33,4	0,9757
		12h s/	587	41,6	0,7716	721	39,3	0,9979
		8h c/	1.402	40,1	0,7535	1.834	33,6	1
		12h c/	1.468	20,9	0,953	1.393	46,9	0,9771
	Apicoam.	0h s/	842	43,3	0,9566	xx	xx	xx
		4h s/	1244	33,3	0,9115	xx	xx	xx
		12h s/	633	41,6	0,8756	xx	xx	xx
		8h s/	xx	xx	xx	956	38,2	0,988
		8h c/	858	38,4	0,9944	xx	xx	xx
		12h c/	1194	38,6	0,9609	1103	47,6	0,9012





**FIGURA 6.8** Envoltórias Variando Intervalo de Tempo e Uso de Argamassa Idade: 120 dias; Tratamento de Camada: Limpeza com Ar Comprimido; e Temperatura da Superfície: 45°C



**FIGURA 6.15** Envoltórias Variando Intervalo de Tempo Utilizando Argamassa.  
 Idade: 120 dias; Tratamento de Camada: Ar Comprimido; e Temperatura da Superfície: 25°C

**TABELA 6.36** Comparação dos Resultados do Programa Experimental Complementar II por Tensão Normal com o Maciço Fora da Junta (Matriz de CCR)

INTERV. DE LANÇAMENTO ARGAMASSA DE LIGAÇÃO	PARÂMETRO	TENSÃO NORMAL (kPa)		
		900	1800	2700
Testemunhos do Maciço Fora da Junta (Matriz)				
Sem Junta	H (kPa)	2346	2960	3575
Testemunhos Prismáticos				
4h – sem argamassa	Média (kPa)	1814	2118	3237
	% Matriz	77%	72%	91%
8h – sem argamassa	Média (kPa)	1617	2455	3108
	% Matriz	69%	83%	87%
24h – com argamassa	Média (kPa)	2173	3147	4022
	% Matriz	93%	106%	113%

### Corpos-de-Prova Moldados

4h – sem argamassa	Média (kPa)	2267	3097	3699
	% Matriz	97%	105%	103%
24h – com argamassa	Média (kPa)	1929	3036	3802
	% Matriz	82%	103%	106%

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# ELASTIC PROPERTIES



# Ensaio com Concreto Endurecido

- Resist. à compressão
- Massa específica
- Resist. tração simples  
Dispositivo Leroy
- Resist. à tração  
diametral
- Módulo de elasticidade
- Permeabilidade



TRAÇÃO SIMPLES



TRAÇÃO DIAMETRAL



MÓDULO DE ELASTICIDADE



# THERMAL PROPERTIES

# SPECIFIC HEAT

por w pacelli



# THERMAL DIFUSIVITY

por w pacelli



# COEFFICIENT OF THERMAL EXPANSION



# CREEP CHARACTERISTICS



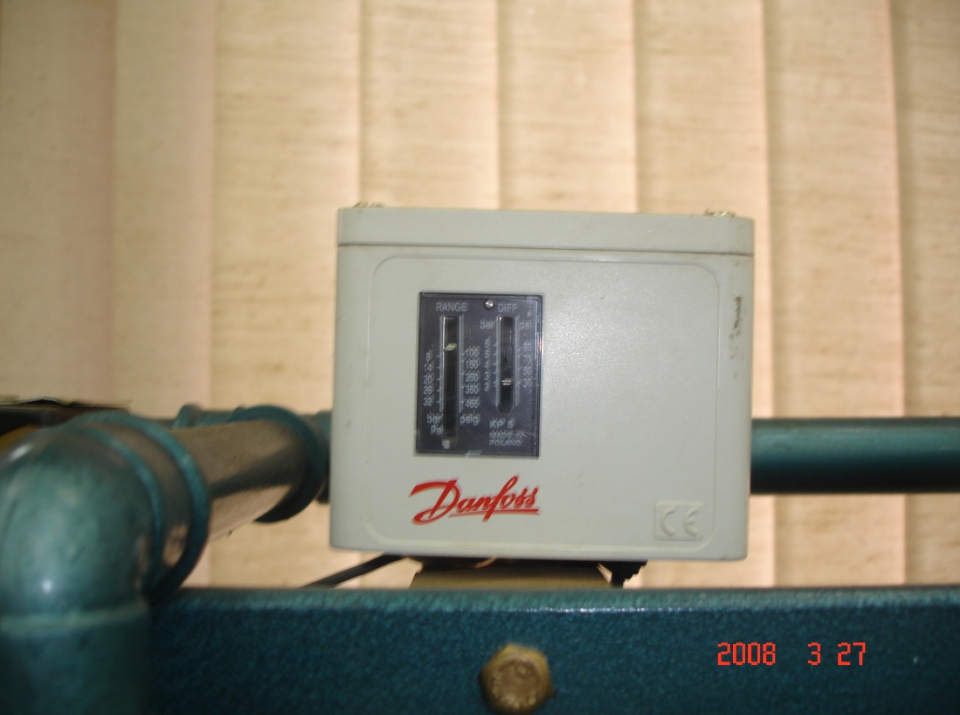




# PERMEABILITY

- Basalto
- Granito
- Gnaisse
- Gabro
- Micaxisto
- Quartzo Micaxisto
- Metagrauvaque
- Xisto







## Permeabilidade CCR Fresco: Granito

Permeabilidade (m/s)		Quantidade	%	$C_{\min}$ (kg/m <sup>3</sup> )	A/C <sub>máx</sub>	Total Finos <sub>min</sub> (kg/m <sup>3</sup> )
1.10 <sup>-9</sup> até 9.10 <sup>-9</sup>	1,00E-09	1	2,1	100	1,55	156
1.10 <sup>-8</sup> até 9.10 <sup>-8</sup>	1,00E-08	7	14,9	80	1,28	162
1.10 <sup>-7</sup> até 9.10 <sup>-7</sup>	1,00E-07	39	83,0	80	1,75	176
Total		47	100,0			

## Permeabilidade CCR Endurecido: Granito

Permeabilidade (m/s)		Quantidade	%	$C_{\min}$ (kg/m <sup>3</sup> )	A/C <sub>máx</sub>	Total Finos <sub>min</sub> (kg/m <sup>3</sup> )
1.10 <sup>-12</sup> até 9.10 <sup>-12</sup>	1,00E-12	47	48,0	60	2,28	90
1.10 <sup>-11</sup> até 9.10 <sup>-11</sup>	1,00E-11	33	33,7	60	2,21	90
1.10 <sup>-10</sup> até 9.10 <sup>-10</sup>	1,00E-10	16	16,3	40	3,43	90
1.10 <sup>-9</sup> até 9.10 <sup>-9</sup>	1,00E-09	2	2,0	80	1,35	202
1.10 <sup>-8</sup> até 9.10 <sup>-8</sup>	1,00E-08	0	0,0	---	---	---
1.10 <sup>-7</sup> até 9.10 <sup>-7</sup>	1,00E-07	0	0,0	---	---	---
Total		98	100,0			

Permeabilidade CCR Fresco: Gabro

Permeabilidade (m/s)		Quantidade	%	C <sub>min</sub> (kg/m <sup>3</sup> )	A/C <sub>máx</sub>	Total Finos <sub>min</sub> (kg/m <sup>3</sup> )
1.10 <sup>-9</sup> até 9.10 <sup>-9</sup>	1,00E-09	0	0,0	---	---	---
1.10 <sup>-8</sup> até 9.10 <sup>-8</sup>	1,00E-08	3	75,0	100	1,42	257
1.10 <sup>-7</sup> até 9.10 <sup>-7</sup>	1,00E-07	1	25,0	100	1,36	259
Total		4	100,0			

Permeabilidade CCR Endurecido: Gabro

Permeabilidade (m/s)		Quantidade	%	C <sub>min</sub> (kg/m <sup>3</sup> )	A/C <sub>máx</sub>	Total Finos <sub>min</sub> (kg/m <sup>3</sup> )
1.10 <sup>-12</sup> até 9.10 <sup>-12</sup>	1,00E-12	7	63,6	100	1,6	274
1.10 <sup>-11</sup> até 9.10 <sup>-11</sup>	1,00E-11	4	36,4	90	1,71	246
1.10 <sup>-10</sup> até 9.10 <sup>-10</sup>	1,00E-10	0	0,0	---	---	---
1.10 <sup>-9</sup> até 9.10 <sup>-9</sup>	1,00E-09	0	0	---	---	---
1.10 <sup>-8</sup> até 9.10 <sup>-8</sup>	1,00E-08	0	0	---	---	---
1.10 <sup>-7</sup> até 9.10 <sup>-7</sup>	1,00E-07	0	0	---	---	---
Total		11	100			

Permeabilidade CCR Fresco: Gnaisse

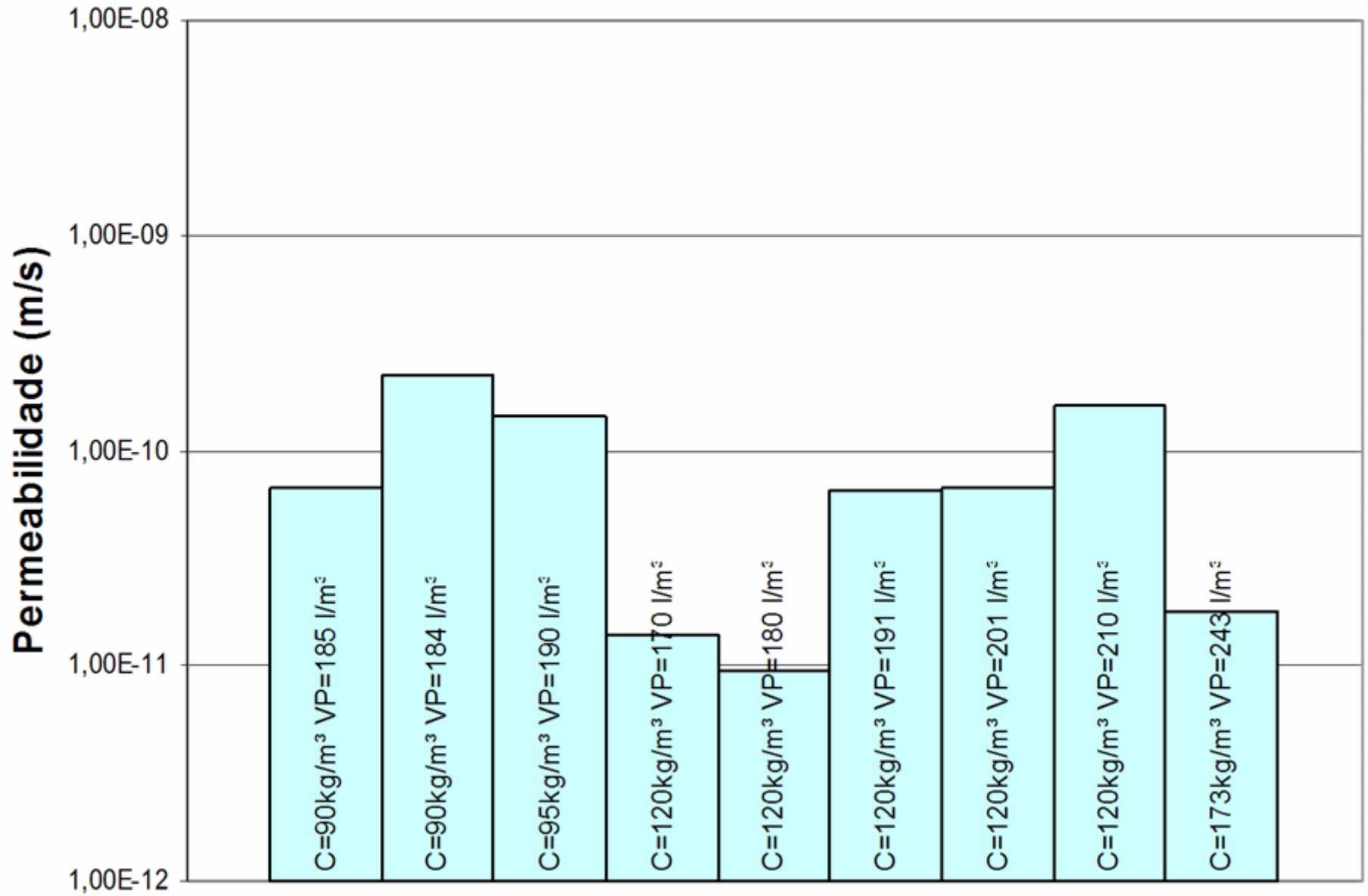
Permeabilidade (m/s)		Quantidade	%	$C_{\min}$ (kg/m <sup>3</sup> )	A/C <sub>máx</sub>	Total Finos <sub>min</sub> (kg/m <sup>3</sup> )
1.10 <sup>-9</sup> até 9.10 <sup>-9</sup>	1,00E-09	1	9,1	80	1,88	290
1.10 <sup>-8</sup> até 9.10 <sup>-8</sup>	1,00E-08	9	81,8	80	2,16	226
1.10 <sup>-7</sup> até 9.10 <sup>-7</sup>	1,00E-07	1	9,1	130	1,35	272
Total		11	100,0			

Permeabilidade CCR Endurecido: Gnaisse

Permeabilidade (m/s)		Quantidade	%	$C_{\min}$ (kg/m <sup>3</sup> )	A/C <sub>máx</sub>	Total Finos <sub>min</sub> (kg/m <sup>3</sup> )
1.10 <sup>-12</sup> até 9.10 <sup>-12</sup>	1,00E-12	1	7,7	120	1,02	200
1.10 <sup>-11</sup> até 9.10 <sup>-11</sup>	1,00E-11	5	38,5	90	1,39	160
1.10 <sup>-10</sup> até 9.10 <sup>-10</sup>	1,00E-10	5	38,5	85	1,6	160
1.10 <sup>-9</sup> até 9.10 <sup>-9</sup>	1,00E-09	1	7,7	70	1,8	203
1.10 <sup>-8</sup> até 9.10 <sup>-8</sup>	1,00E-08	0	0,0	---	---	---
1.10 <sup>-7</sup> até 9.10 <sup>-7</sup>	1,00E-07	1	7,7	90	1,3	160
Total		13	100			

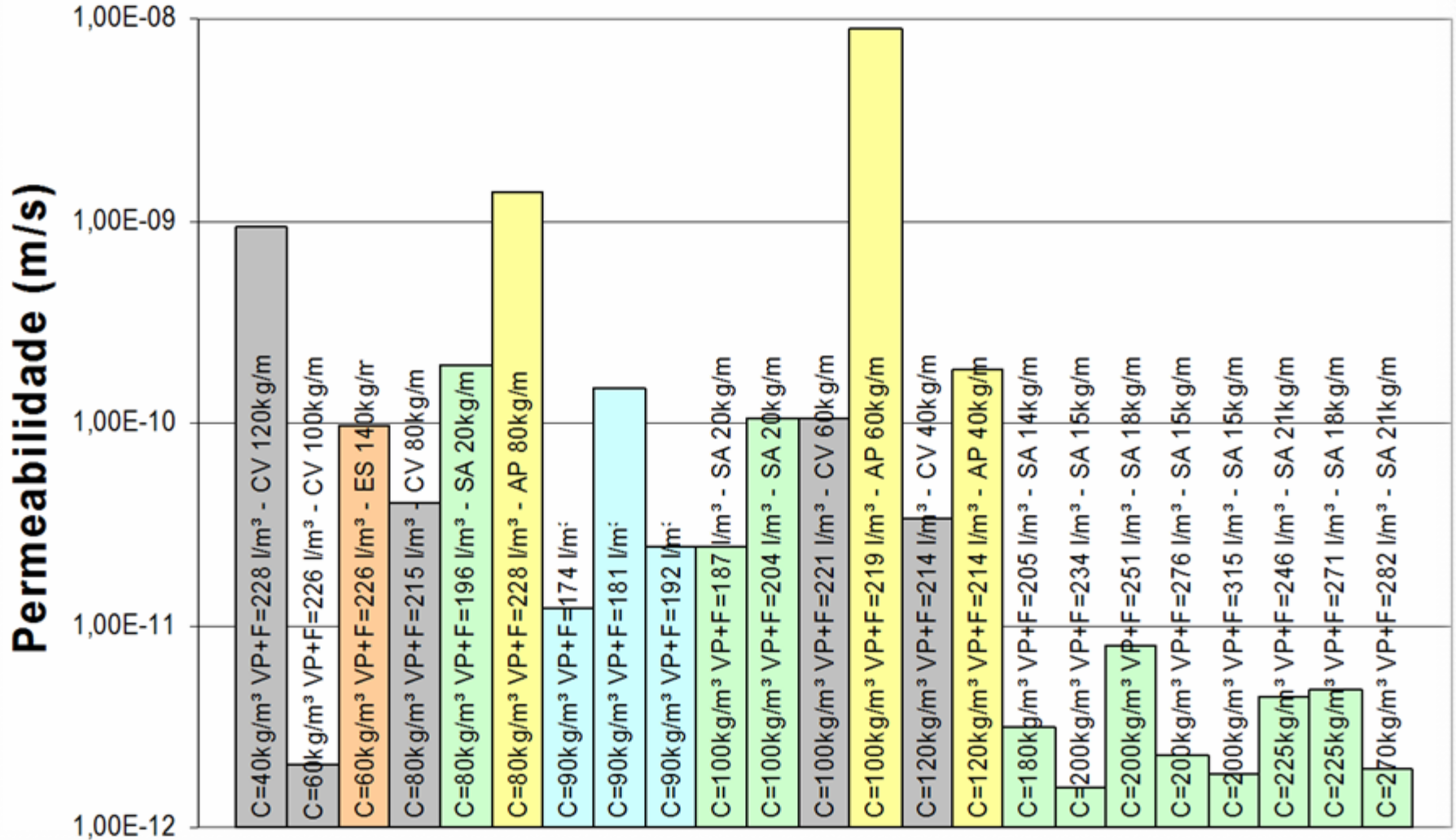


## Basalto - Volume de Pasta



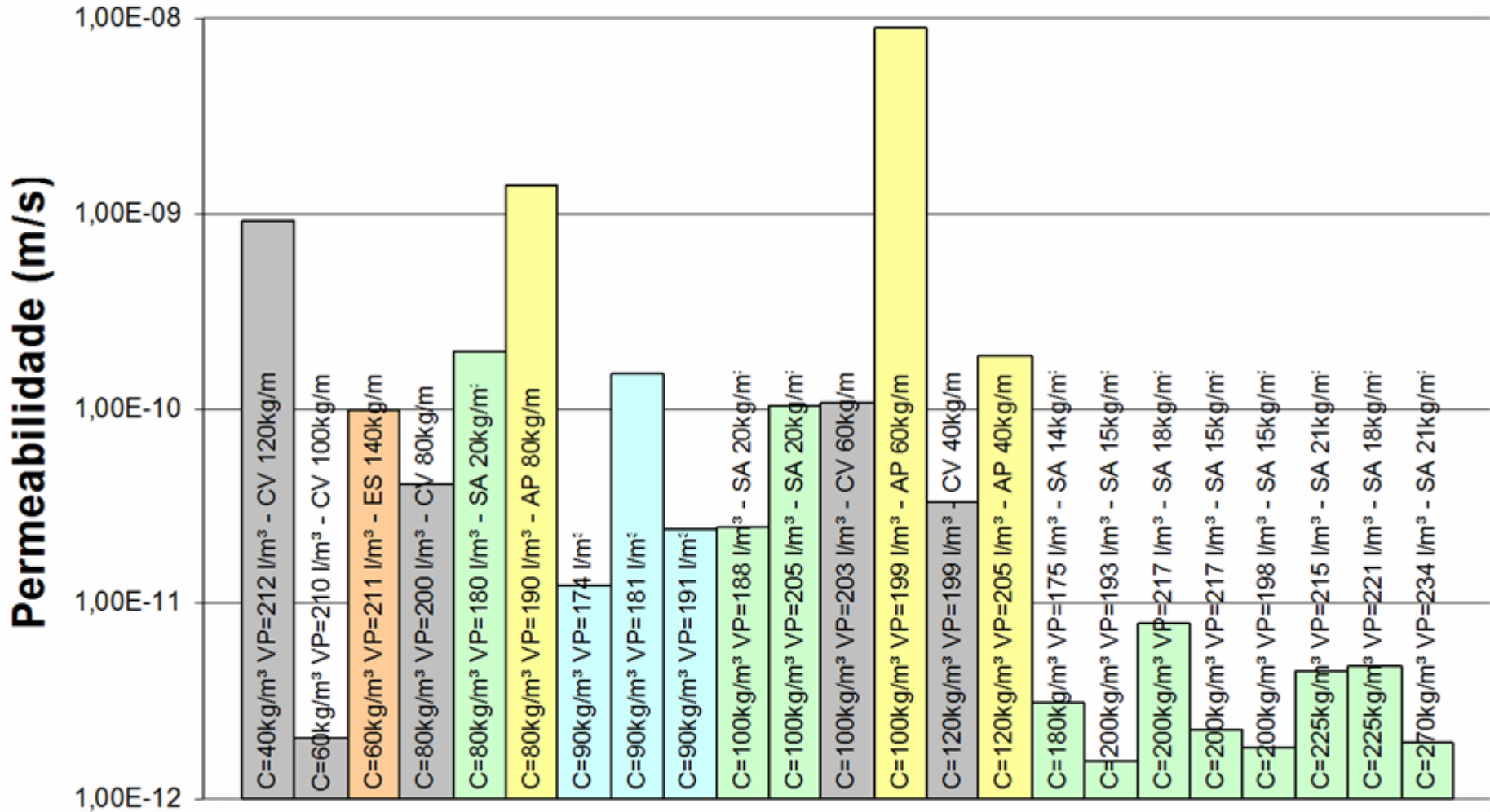
SA	sem adição
PZ	silica ativa
ES	Pozolana
CV	Escória
AP	Cinza Volante
	Agregado Pulverizado

### Granito - Volume de Pasta + Finos



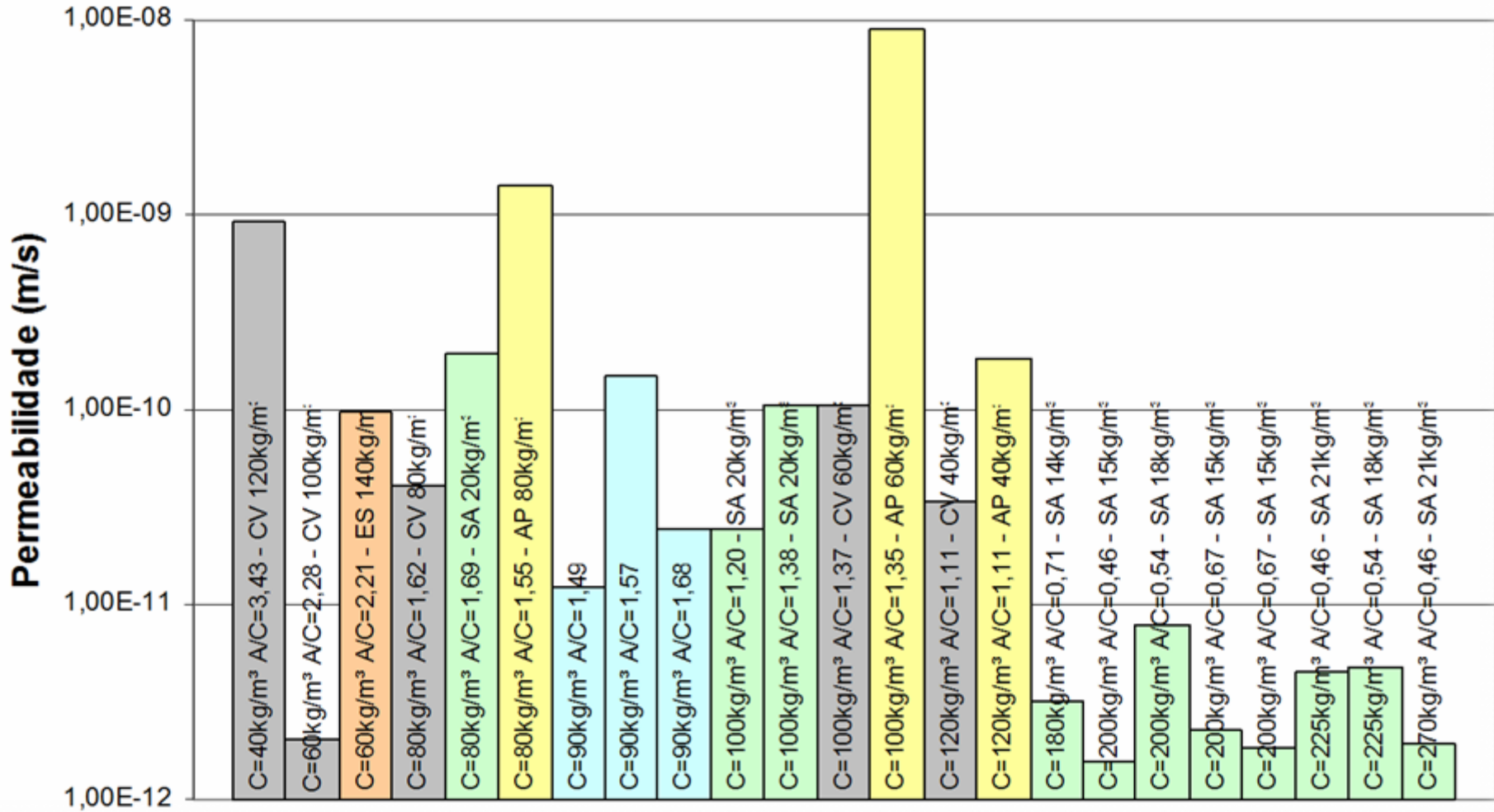
	sem adição
SA	sílica ativa
PZ	Pozolana
ES	Escória
CV	Cinza Volante
AP	Agregado Pulverizado

### Granito - Volume de Pasta



	sem adição
SA	sílica ativa
PZ	Pozolana
ES	Escória
CV	Cinza Volante
AP	Agregado Pulverizado

### Granito - Fator A/C





# PERMEABILIDADE-SERRA DO FACÃO

## ENSAIOS DE PERMEABILIDADE

Registro LABC	Registro Obra	Identificação	Coeficiente de Permeabilidade (m/s)	
			Individual	
1.0106.2008	CTSF.0103.08	EX-41	CP 1	$3,056.10^{-11}$
			CP 2	$3,111.10^{-11}$
			CP 3	$2,286.10^{-11}$
			CP 4	Em verificação
1.0107.2008	CTSF.0104.08	Série 146	CP 1	Não percolou
			CP 2	Não percolou
1.0108.2008	CTSF.0105.08	Série 159	CP 1	$1,810.10^{-12}$
			CP 2	Não percolou
			CP 3	$6,218.10^{-13}$
1.0109.2008	---	Série 174	CP 1	Não percolou
			CP 2	$3,450.10^{-13}$
			CP 3	Não percolou

EX-41 Dosagem de CCR com  $100 \text{ kg/m}^3$  lançado na Pista Experimental

Série 146 Dosagem de CCV com  $230 \text{ kg/m}^3$  lançado na Pista Experimental

Série 159 Dosagem de CCV com  $190 \text{ kg/m}^3$  lançado na Pista Experimental ( Consumo utilizado no paramento de montante da barragem de CCR) Traço E 50 C 02

Série 174 Dosagem de CCV com  $190 \text{ kg/m}^3$  lançado na regularização da barragem bloco 9.( Consumo utilizado no paramento de montante da barragem de CCR) Traço E 50 C 02

# ENSAIOS TRIAXIAIS - EQUIPAMENTOS



# ENSAIOS TRIAXIAIS - EQUIPAMENTOS



LVDT's diametralmente opostos  
(deformações axiais)

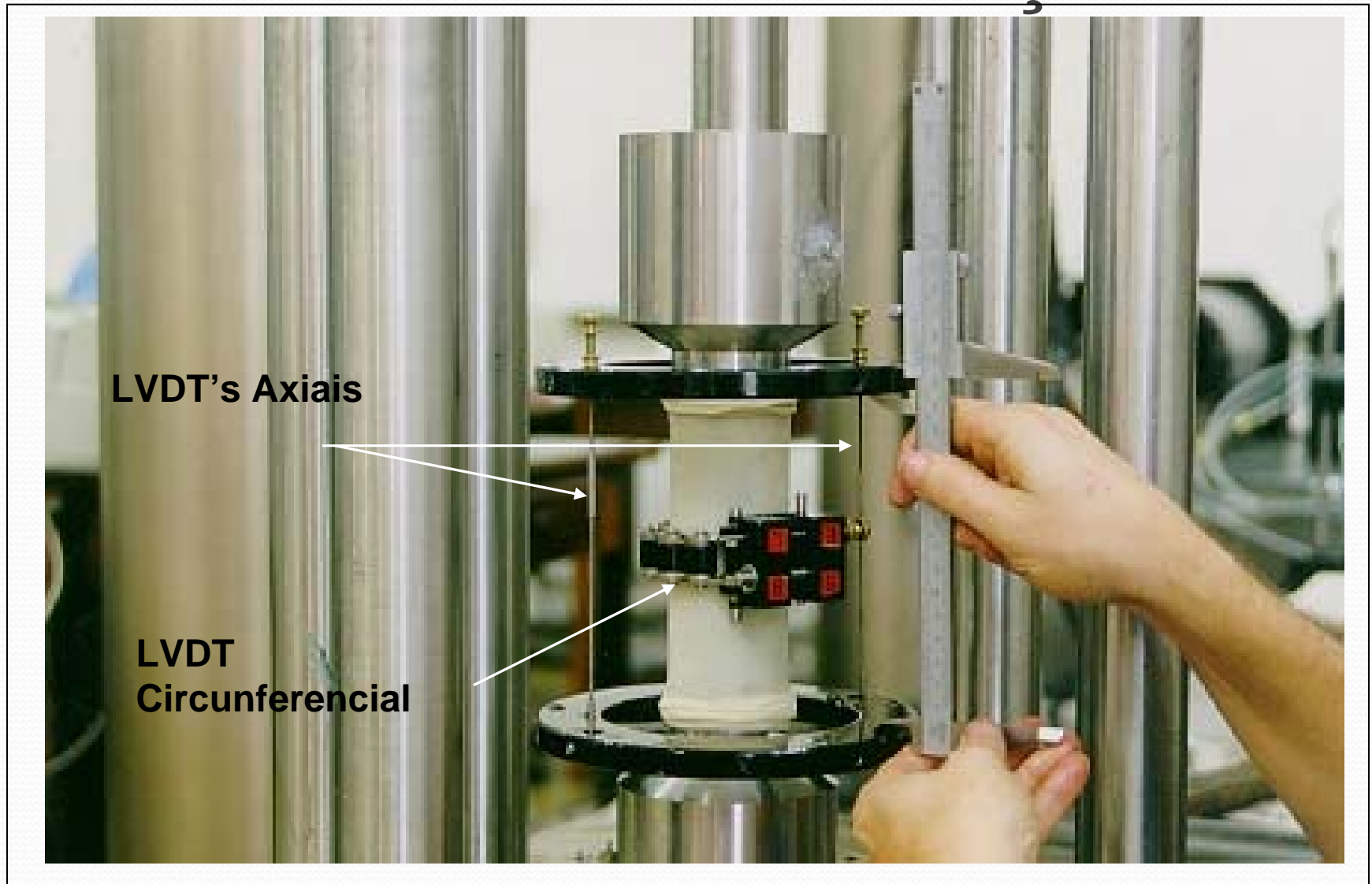
LVDT circunferencial

Anel fixador dos LVDT's axiais

Cabeçote de aço de alta dureza



# ENSAIOS TRIAXIAIS - EXECUÇÃO



# ENSAIOS TRIAXIAIS - EXECUÇÃO



# ENSAIOS TRIAXIAIS - EXECUÇÃO



# ENSAIOS TRIAXIAIS - EXECUÇÃO



# CORE DRILLING & TESTING

Length is 15.03 m. Core samples are shown in Fig. 2

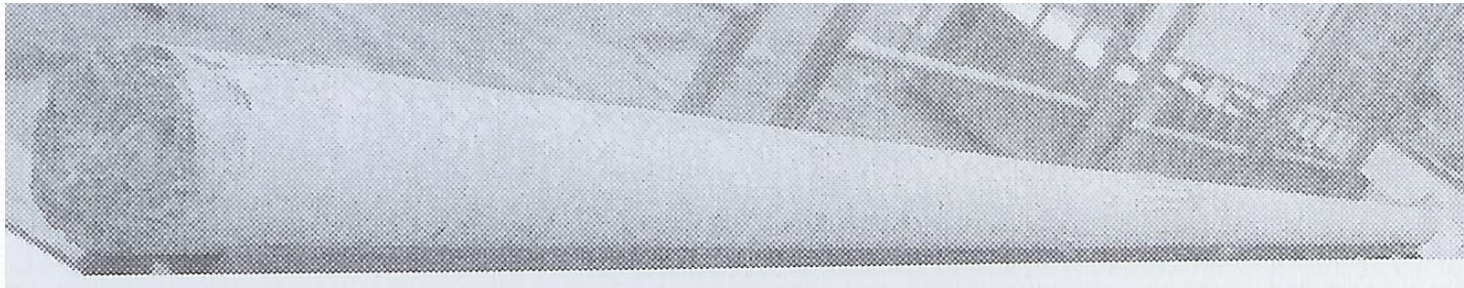


Fig. 2 A longest core sample of Longtan RCC dam (15.03 m long)



# Concrete Society Technical Report No.11 including Addendum (1987)

## Concrete core testing for strength Report of a Concrete Society Working Party

### The Concrete Society

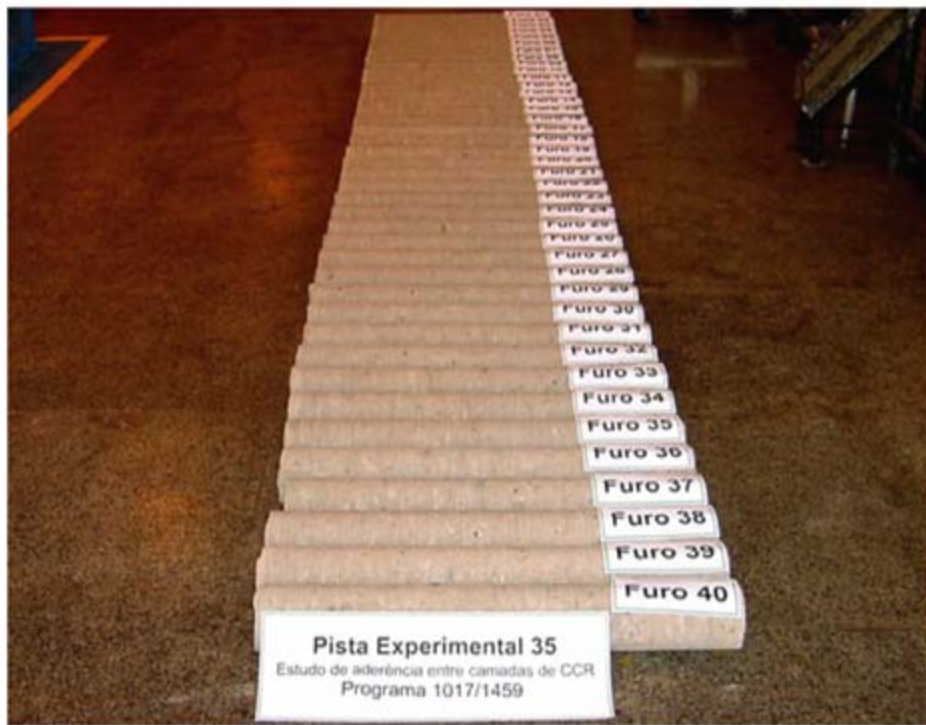


## Summary

**This report includes the May 1976 edition of Technical Report No. 11, together with an Addendum (1987). The original report provides recommended procedures for obtaining and the compressive testing of concrete cores and for the interpretation of the results. Evidence from practice and research is provided for the formulae and conversion factor recommended.**

**The Addendum takes account of changes in British Standards, practical experience and research results in confirming many of the recommendations, and in recommending modifications to some procedures for obtaining and compressive testing of cores and interpreting results. It includes a review of published data since 1976 and makes recommendations for further research. The report and addendum should be read in conjunction with BS 1881 : Part 129 : 1983 and BS 6089 : 1981.**





Estimated Actual Strength

$$= \frac{2.5}{1.5 + 1/\lambda} \times \text{Core Strength}$$

for cores drilled in a horizontal direction

Estimated Actual Strength

$$= \frac{2.3}{1.5 + 1/\lambda} \times \text{Core Strength}$$

for cores drilled in a vertical direction.

## **Appendix 1 to Part 3: Correcting core strength for the influence of Excess Voidage**

The Excess Voidage of a core is that amount by which the Actual Voidage exceeds the voidage of a well made cube of the same concrete (the Potential Voidage). Since the Potential Voidage is never known in practical situations, its value is assumed where necessary to be 0.5%.

Excess Voidage cannot easily be determined with precision, but two independent methods of estimating it are recommended.

### *(1) By visual means (see Appendix 2)*

This method is subjective but independent of information other than that evidenced by the core itself and the assumption that the Potential Voidage is 0.5%.

(2) *From density test results*

This method is objective but dependent upon the precision with which the Potential Density of the concrete has been established and upon the degree of water saturation of the voids.

In the density test method, the Excess Voidage of a core is given by the expression:

$$\frac{D_p - D_a}{D_p - k \times 1000} \times 100\%$$

where ( $D_p$ ) is the Potential Density (clause P/3.2.2.7); ( $D_a$ ) is the Actual Density of the core water-soaked (clause 3.4.2.4); 1000 is the density of water (all three density values being expressed in  $\text{kg/m}^3$ ); and  $k$  is the fraction of the voids in the core resulting from imperfect compaction and filled with water when  $D_a$  is measured.

The value of  $k$  is assumed to be 0.5 unless there are agreed reasons for adopting another value, so that

$$\text{Estimated Excess Voidage} = \frac{D_p - D_a}{D_n - 500} \times 100\%$$

Excess Voidage (%)	Strength multiplying factor
0	1.00
0.5	1.04
1.0	1.08
1.5	1.13
2.0	1.18
2.5	1.23
3.0	1.28
3.5	1.33
4.0	1.39
4.5	1.45
5.0	1.51







# CAPANDA



# CANA-BRAVA

UHE CANA BRAVA  
BARRAGEM - BLOCO 1 - Montante  
FURO BMDH - 11 - DIÂMETRO 15cm  
TESTEMUNHO 01.11: CCV  
COMPRIMENTO: 0,79m  
ELEVAÇÃO: 312,54m

UHE CANA BRAVA  
BARRAGEM - BLOCO 1 - Montante  
FURO BMDH - 13 - DIÂMETRO 15cm  
TESTEMUNHO 03.13: CCV  
COMPRIMENTO: 0,61m  
ELEVAÇÃO: 312,54m

UHE CANA BRAVA  
BARRAGEM - BLOCO 1 - Montante  
FURO BMDH - 12 - DIÂMETRO 15cm  
TESTEMUNHO 01.12: CCV  
COMPRIMENTO: 0,78m  
ELEVAÇÃO: 312,77m

PEIXE



# NORMALIZAÇÃO DE ENSAIOS E PROCEDIMENTOS PARA O CONCRETO COMPACTADO COM ROLO DE BARRAGENS

50º Congresso Brasileiro do Concreto - IBRACON – Salvador/BA  
Agosto/2008

Foram elaborados 4 textos base para sugestão de início dos trabalhos de normalização de ensaios e procedimentos para o CCR no âmbito do CB-18.

Os textos base sugeridos serão disponibilizados para avaliação do meio técnico competente de forma a efetivar o texto definitivo para as normas, as quais terão como base o layout adotado para a normalização dos ensaios de reatividade álcali-agregado.

## TEXTOS BASE ELABORADOS:

1. **Terminologia.:** Trata dos principais termos e definições relacionados ao concreto compactado com rolo de barragens.
2. **Preparação em Laboratório:** Em analogia à ABNT NBR 12821, prescreve a metodologia e ensaios para concreto compactado com rolo produzido em laboratório.
3. **Ensaio de Laboratório no Concreto Fresco:** Descreve os métodos de ensaios de consistência, massa unitária e teor de umidade do concreto fresco.
4. **Requisitos de Aplicação da Técnica:** Descreve os principais requisitos e limites necessários para aplicação do concreto compactado com rolo. Além das preocupações necessárias, são apresentados os métodos de aplicação da técnica (tradicional e rampado).

**TEXTOS BASE A SEREM ELABORADOS:**

**1. Ensaio de Campo**

**2. Permeabilidade do Concreto Fresco**



# BRAZILIAN STANDARDS

## NORMALIZAÇÃO DE ENSAIOS E PROCEDIMENTOS PARA O CONCRETO COMPACTADO COM ROLO PARA BARRAGENS

- Agosto de 2008 -

Os textos base em questão são sugestões para a normalização de ensaios e procedimentos relacionados ao concreto compactado com rolo para aplicação em barragens. Todos eles passarão pelo processo de discussão no âmbito do CB-18, não sendo os textos definitivos para a criação das normas.

# BRAZILIAN STANDARDS

- *Texto Base 1:*
- **Concreto Compactado com Rolo – Terminologia.**
- Trata dos principais termos e definições relacionados ao concreto compactado com rolo de barragens.
- *Texto Base 2:*
- **Concreto Compactado com Rolo – Preparação em Laboratório.**
- Similar à ABNT NBR 12821, prescreve a metodologia e ensaios para concreto compactado com rolo produzido em laboratório.

# BRAZILIAN STANDARDS

- **Texto Base 3:**
- **Concreto Compactado com Rolo – Ensaaios de Laboratório em Concreto Fresco.**
- Descreve os métodos de ensaios de consistência, massa unitária e teor de umidade do concreto fresco.
- **Texto Base 4:**
- **Concreto Compactado com Rolo – Requisitos de Aplicação da Técnica.**
- Descreve os principais requisitos e limites necessários para aplicação do concreto compactado com rolo. Além das preocupações necessárias, são apresentados os métodos de aplicação da técnica (tradicional e rampado).

# BRAZILIAN STANDARDS

- *Textos base em processo de elaboração:*
- 
- **Concreto Compactado com Rolo – Ensaio de Campo.**
- **Concreto Compactado com Rolo – Permeabilidade do Concreto Fresco.**
- 
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# RCC 2008 50 CBC -CONFERENCE

- **Quod erat demonstrandum**
- - *Opus Caementitium Adstrinctum (OCA)*
- *Quod est máxima proprietas OCA : ?*
- *Cortezia :Eng. Flavio Mamede Pereira Gomes*