CONCRETO
COLLOQUIA 2003

Universidade deSão Paulo
Escola de Engenharia deSão Carlos
Jubileu de Ouro
2003

Edifício *e-Tower*

Recorde Mundial Concreto Colorido de Alto Desempenho

Eliron Souto, concreto
Jorge Batlouni, construtor
Paulo Helene, consultor
Ricardo França, projetista estrutural

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Edifício e-Tower

Recorde Mundial de Concreto colorido de alto desempenho

Parte 3 – Concreto do e-Tower

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Concrete Design

Materials & Lab. Tests

Concrete Lab. Composition

Concrete Mixed in Trucks

Casting Columns in Parking Area

Por quê ?? **Resistências, cor, trabalhabilidade, temperatura**

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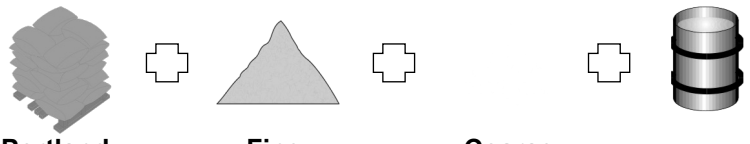
HPC composition



Portland cement **Fine aggregate** **Coarse aggregate** **water**

Concreto comum

Admixtures

Additions + Pigments

HPCC

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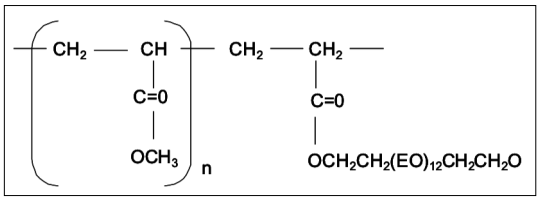
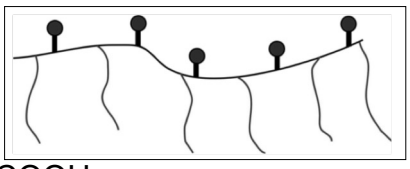
POLICARBOXILATO



(a) Monômero de um policarboxilato

- Conhecidos comercialmente como de 3ª geração;
- Redução de até 40% de água da mistura
- Possuem grupos carboxílicos COOH;
- Cadeia lateral longa.



(b) Esquematização da molécula

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superplasticizer

Cimento Portland + Água

⇩

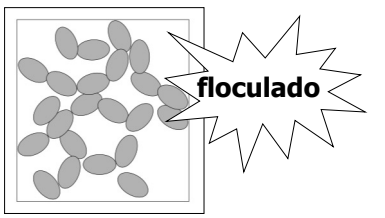
Floculação

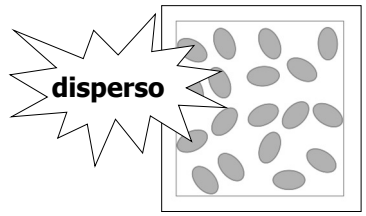
⇩

aprisonamento de água entre os grãos de cimento

⇩

redução da fluidez e da área específica disponível para hidratação





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superplasticizer

Cimento Portland + Água

⇩

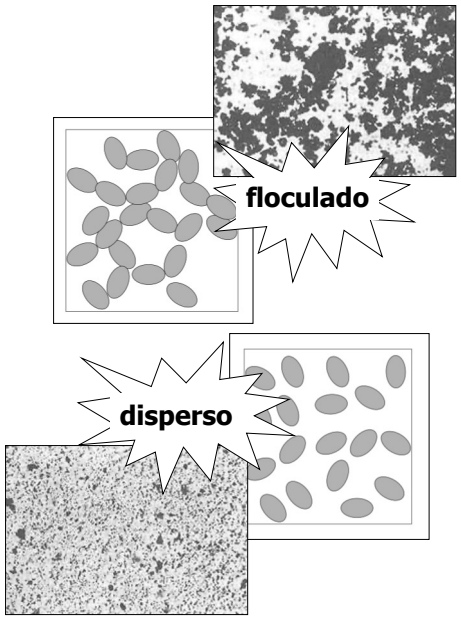
Floculação

⇩

aprisonamento de água entre os grãos de cimento

⇩

redução da fluidez e da área específica disponível para hidratação



Mineral Additions

Para obter maior compacidade e maior resistência mecânica

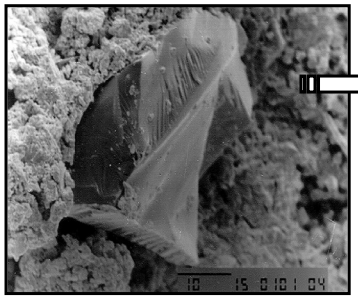
⇩

adição de minerais ativos

Metakaolim and silica fume

- **estrutura mais compacta**
- **reagem com a cal livre melhorando a resistência e durabilidade.**

MINERAL ADDITIONS



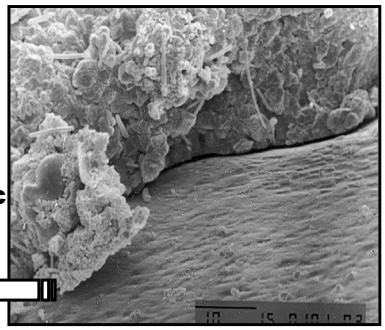
Conventional Concrete

Aumento 1500x

Concrete with

Metakaolin &

Silica Fume



Aumento 1500x

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RED PIGMENT

- ✓ Iron oxide Fe_2O_3 > 98%
- ✓ grau 8 de solidez a luz solar
- ✓ 0,5% de sais solúveis
- ✓ 99,95% diâmetro de particula < 0,045mm (#325) 0,05% de retenção
- ✓ Densidade 4.500 kg/m^3
- ✓ Formato Partícula: Esférica
- ✓ EN 12878 y ASTM C 979

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Casting Columns in Parking Area

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Materials

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Tempo e temperatura

Controle de tempo	
Horário de início da mistura	12:55
Horário da saída da central	13:35
Horário chegada obra	14:30
Horário término da concretagem	16:00

Temperatura concreto na chegada na obra
37,5 ºC

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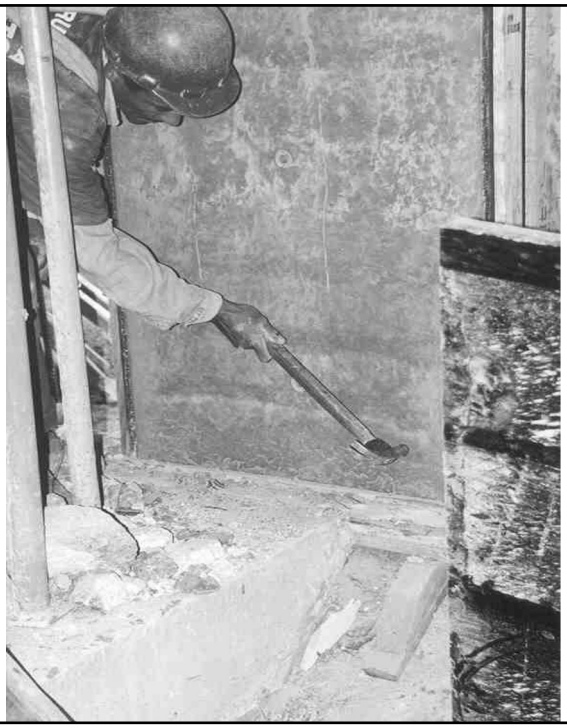

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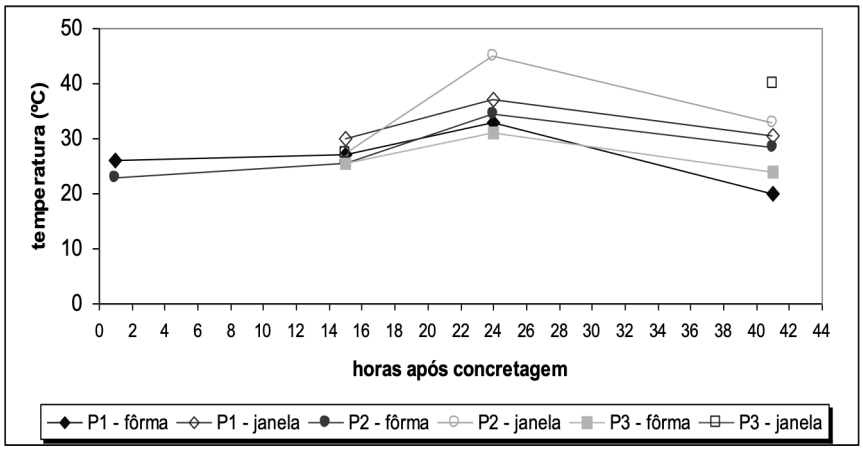
Temperatura



P1 = 133 P2 = 134 P3 = 135

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Dosagem

materiais	teor	quantidade	obs
CPV ARI RS	1,00	460 kg/m^3	460 cim. + 163 escória
adição	0,15	93 kg/m^3	silica & metacaulim
agregado graúdo	1,65	1.027 kg/m^3	basalto, 19mm, MF 6,9, 3.020 kg/m^3
agregado miúdo	0,88	550 kg/m^3	quartz, 2,4mm, MF 2,0, 2.670 kg/m^3
pigmento	0,04	25 kg/m^3	óxido de ferro
superplastificante	0,01	6,2 kg/m^3	policarboxilato
retardador	0,0058	3,6 kg/m^3	acido hydrocarboxálico
água	0,19	135 kg/m^3	W / C = 0,19

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Two Union Square Seattle 1998

f'$_{ca}$	**119 MPa**
Cement	**513 kg/m^3**
Microssilica	**41 kg/m^3**
Coarse aggregate	**1,195 kg/m^3**
Fine aggregate	**682 kg/m^3**
Superplasticizer	**16 kg/m^3**
Retarder	**nihil**
Water	**130 kg/m^3**
W / C	**0.25**
W / C$_m$	**0.23**

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CONCRETAGEM DOS PILARES

Pilares
concreto com pigmento e gelo
Abatimento: 14-20 cm
Temperatura do concreto: 21,5 º C

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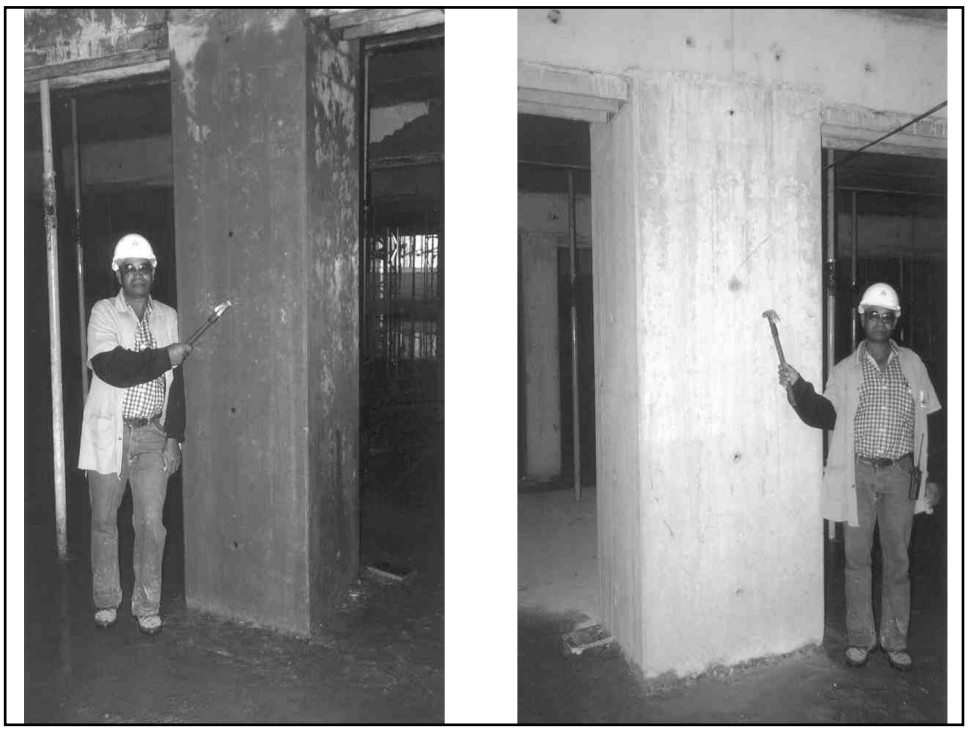

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Vida Útil

- Carbonatação
- Cloretos
- Fuligem
- Fungos
- Lixiviação
- Retração
- Sulfatos

- << pH
- Corrosão
- Fissuras
- Destacamento

Carbonatação

$$t = \frac{e_{CO2}^2}{k_{CO2}^2} \quad \text{(ano)}$$

- e_{co2} → 1 a 5 cm
- k_{co2} → 0.1 a 1.0 cm/ano$^{1/2}$

Carbonatação

e = 2,0 cm

f_{ck}= 15 MPa → t = 8 anos

f_{ck}= 50 MPa → t = 350 anos

f_{ck}= 25 MPa → t = 38 anos

Cloretos - difusão

$$t = \frac{c^2_{Cl}}{4 \cdot z^2 \cdot D^{½}_{ef,Cl}} \text{ (anos)}$$

c_{Cl} → 1 a 5 cm

$D_{ef,Cl}$ → 0,15 a 2,7 cm²/ano

Cloretos - difusão

e = 2,0 cm

f_{ck}= 15 MPa → t = 4 anos

f_{ck}= 50 MPa → t = 150 anos

f_{ck}= 25 MPa → t = 23 anos

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CONTROLE

Resistência à compressão

Módulo de Elasticidade

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Resistência a Compressão

Lote	Local	f_{ck} (MPa)	exemplar	Média	Desvio padrão	Coef. Variação	fck est
1	4º SS	80	4	142,6	7,0	5%	133
2	3º SS	80	4	127,0	5,0	4%	122
3	2º SS	80	4	124,6	7,5	6%	119
4	1º SS	80	4	126,6	5,5	5%	120
5	Térreo	80	8	128,4	7,5	6%	123
6	1º pavimento	80	7	127,4	7,9	6%	110
7	2º pavimento	80	4	125,4	7,1	6%	118
Desvio padrão e coef. variação médio ponderado					7,0	5,5	118

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Claim ID: 22678
Membership Number: 22322

Thursday, May 16, 2002

Thank you for sending us the details of your recent record proposal for 'Best concrete resistance in a building'. After having examined the information you sent, and given full consideration to your proposal, I am afraid we do think that this item is a little too specialised for a body of reference as general as ours.
We receive many thousands of record claims every year and we think you will appreciate that we are bound to favour those which reflect the greatest interest.

Yours sincerely,

Scott Christie
Records Research Services
Guinness World Records

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Dear Paulo,

I have appreciated to read your letter and description of your very high concrete strength achieved in the very beautiful high rise.
At this stage fib is not really focused on selecting and documenting "World Records" in concrete, concrete structures, height of buildings or free spans of bridges.
However, we have full confidence and trust in the documentation prepared and presented by you.
Therefore, I really would recommend you to write a well documented technical paper for the fib Magazine "Structural Concrete" that could be one very relevant place to publish this fascinating story.

Steen Rostam
fib (CEB-FIP)

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Paulo:

I have received your letter regarding the high-strength concrete record.

You have certainly gotten into HSC in a very big way!

We can discuss later which can be the best way….

Terry
ACI President

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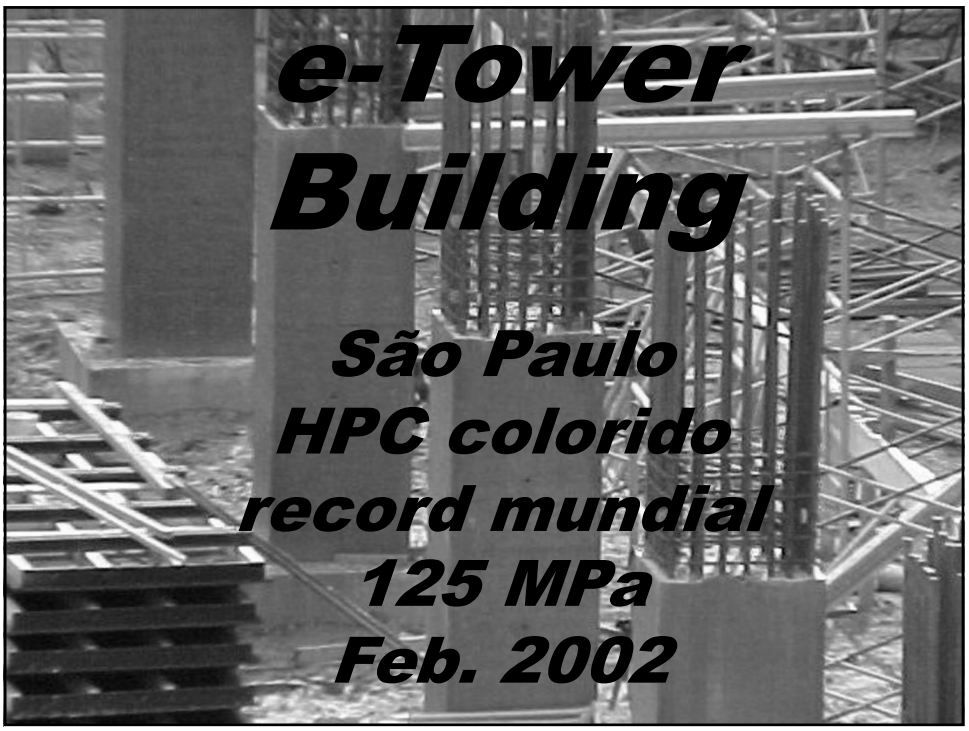

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Propriedades mecânicas

		❑f_{ck} = 118 MPa	❑f_{ck} = 25 MPa
		❑f'_c = 17,000 psi	❑f'_c = 3,600 psi
f_c	7 days	111	18
f_c	28 days	125	32
f_c	63 days	139	37
f_c	91 days	155	39
E_{ci}	28 days	50	30
f_{ct}	28 days	10	3,1
Ultrassom m/s		4950	3250
esclerometria		52	23

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Durabilidade

	f_{ck} 125 MPa	f_{ck} 25 MPa
Carbonatação 28+63d 25ºC 65% 5%	zero	29mm
Absorção H_2O	0,40%	7,5%
Volume vazios	1%	17,5%
Densidade kg/m³	2530	2310
Absorção capilar	0,1 g/cm²	2,7 g/cm²
Ascensão capilar	0 cm	30 cm
Cloretos	43 C	8.400 C
Abrasão cm³/cm²	0,019	0,051

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Vida Útil usando segunda lei de Fick para agressividade por carbonatação 980 anos!!!!

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Resistência a Incêndio e Temperaturas Elevadas

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NISTIR 6726. National Institute of Standards and Technology, 2001.

HSC water-cement ratio 0.22 to 0.57, 51 to 93 MPa.

1. High-strength mixtures made with very low w/cm (0.22) showed less strength loss than with 0.33 w/cm.

2. Explosive spalling was observed when the temperature of the specimen center was in the range of 200 and 325 C.

3. Preload seems to have a mitigating effect on the development of explosive spalling.

4. Concrete samples cast with 0.22 w/cm had a greater potential for spalling under unrestrained condition than samples cast with 0.33 w/cm. However, when the test was conducted under restrained conditions, explosive spalling only occurred with samples cast with 0.33 w/cm.

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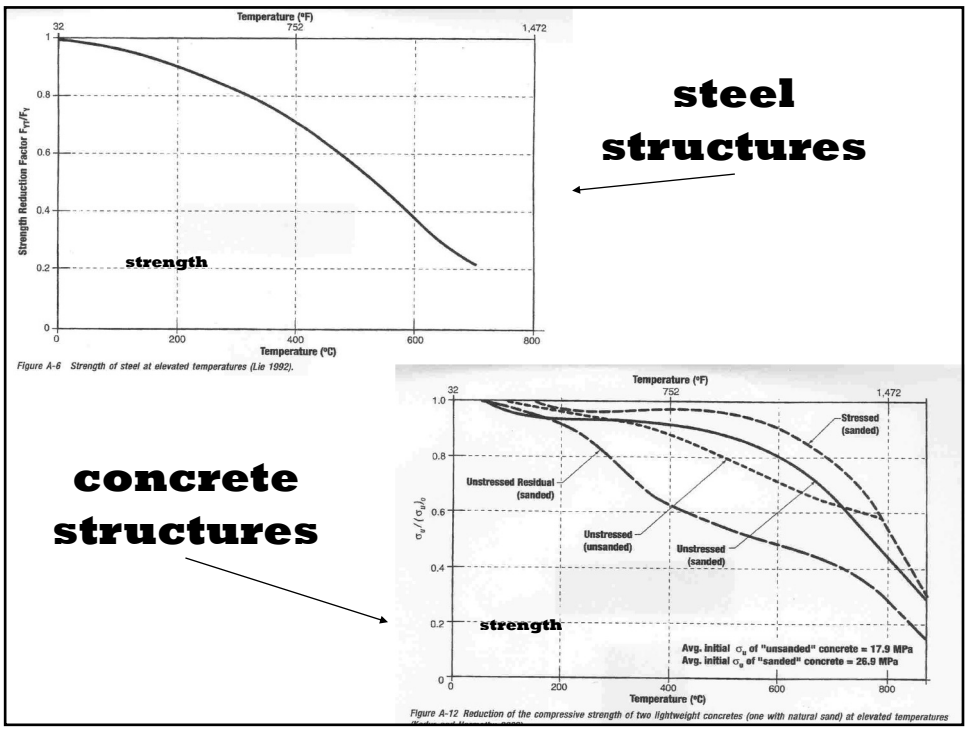

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steel structures

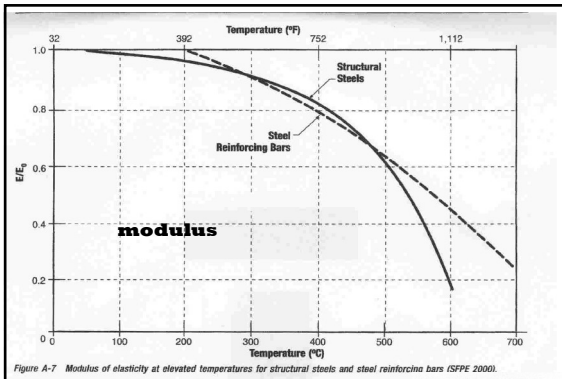
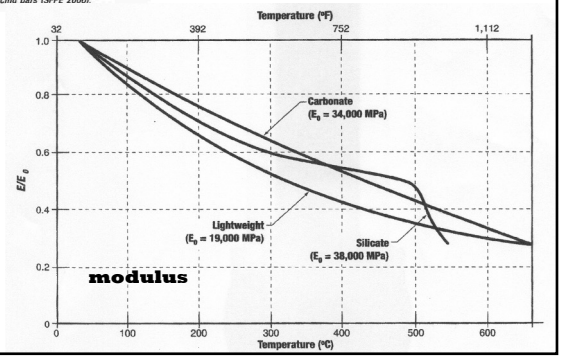


Figure A-7 Modulus of elasticity at elevated temperatures for structural steels and steel reinforcing bars (SFPE 2000).

concrete structures



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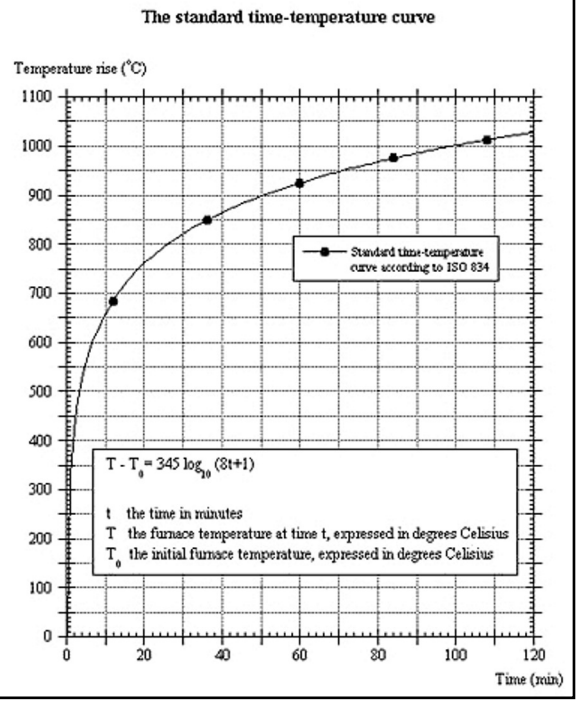
Crescimento da Temperatura ASTM E 119



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Distribuição da temperatura nos perfis metálicos

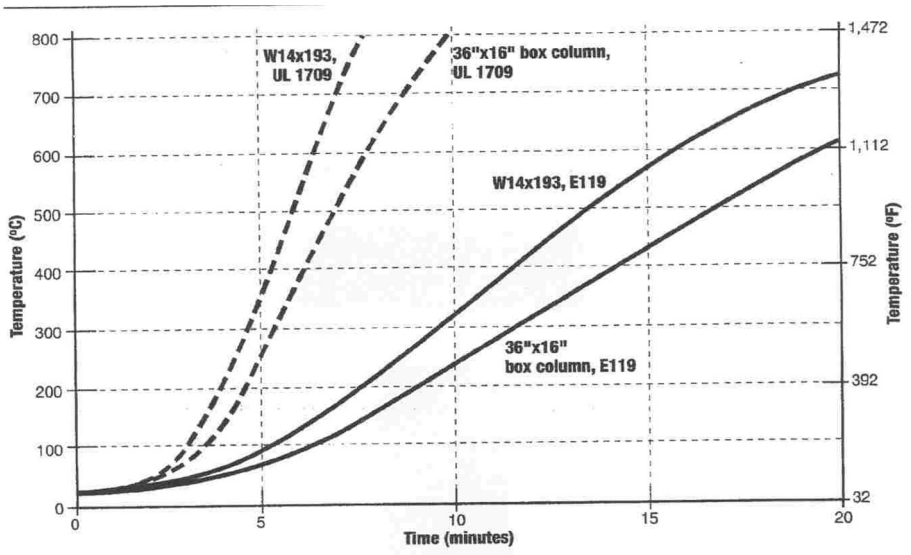

Figure A-9 Steel temperature rise due to fire exposure for unprotected steel column.

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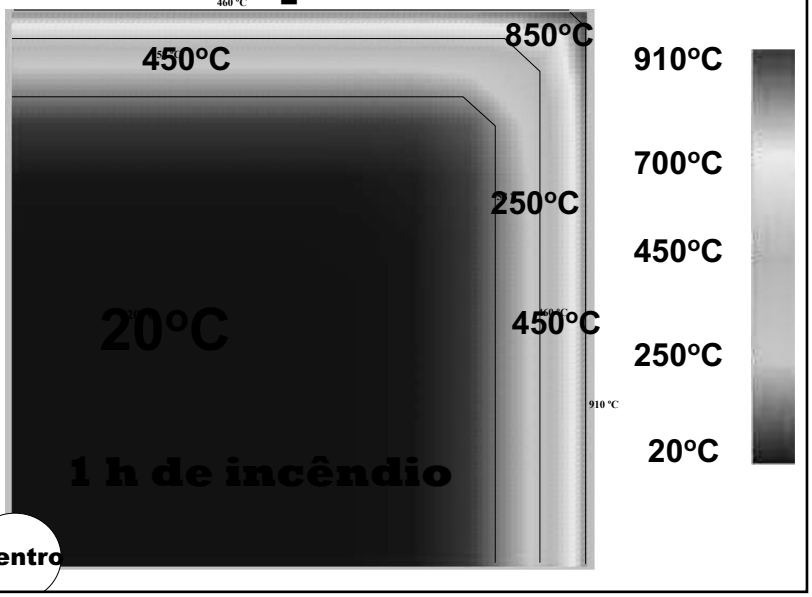
Distribuição das Temperaturas

Concreto pilar 50x50 cm

Polivka & Wilson
UC, 1976
Berkeley

Calmon & Claudio
UFES, 2002
Vitória

Bazant & Kaplan
Northwestern
Logman, 1996



centro

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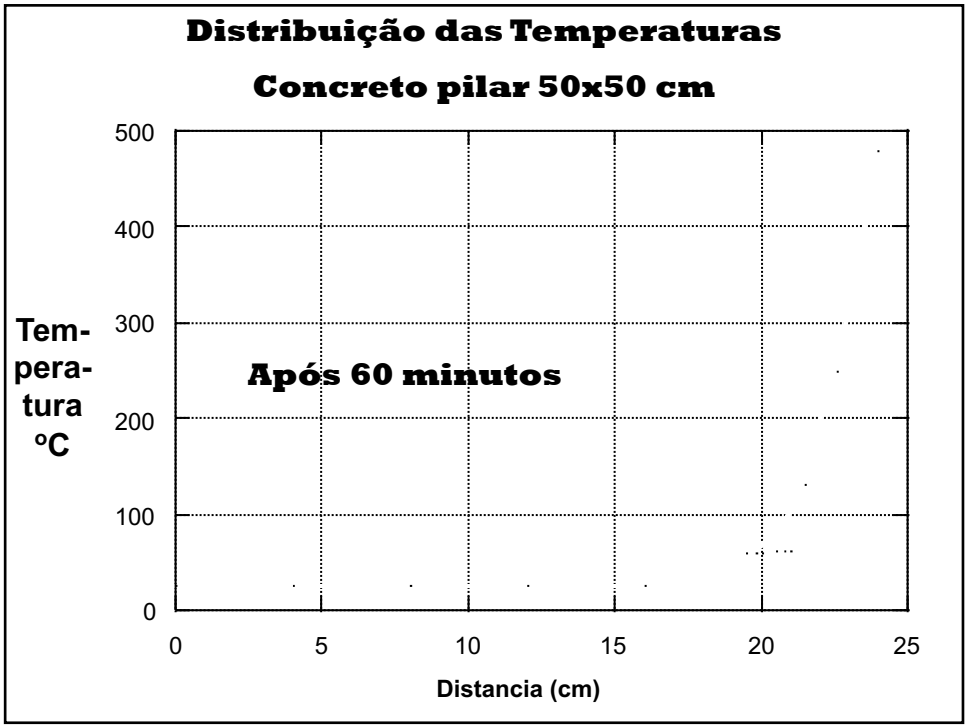

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Sustanaible Development

"Increasing service life of concrete structures we can preserve the natural resources.

If we develop the design and construction ability we can get concrete structures with **500 years** service life. Doing this we can multiply by ten our productivity which means preserve the 90% of them"

Kumar Mehta

Reducing the Environmental Impact of Concrete
Concrete International. ACI, v.23, n. 10, Oct. 2001. p.61-66

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