ACI Fifth International Conference

Innovation in Design

HPC in Brazil "Research, Construction and Records"

Paulo Helene

Civil Eng., MSc, PhD, Full Professor, University of São Paulo
Deputy Chairman of fib (CEB-FIP) Commission 5 "Structural Service Life Aspects"
Chairman of REHABILITAR Network CYTED
Director of GLARilem
IBRACON Conseil Director

Quintana Roo Cancun, December 9-13, 2002 Mexico

1

Thanks very much to

Terry Holland
Raul Husni
Jorge Bernardini

For the help me to translate from Portuguese to English

2

São Paulo Art Museum **1968**
f'_c = 7,000 psi (45 MPa)

3

Niterói Modern Art Museum **1999**
f'_c = 7,500 psi (50 MPa)

4

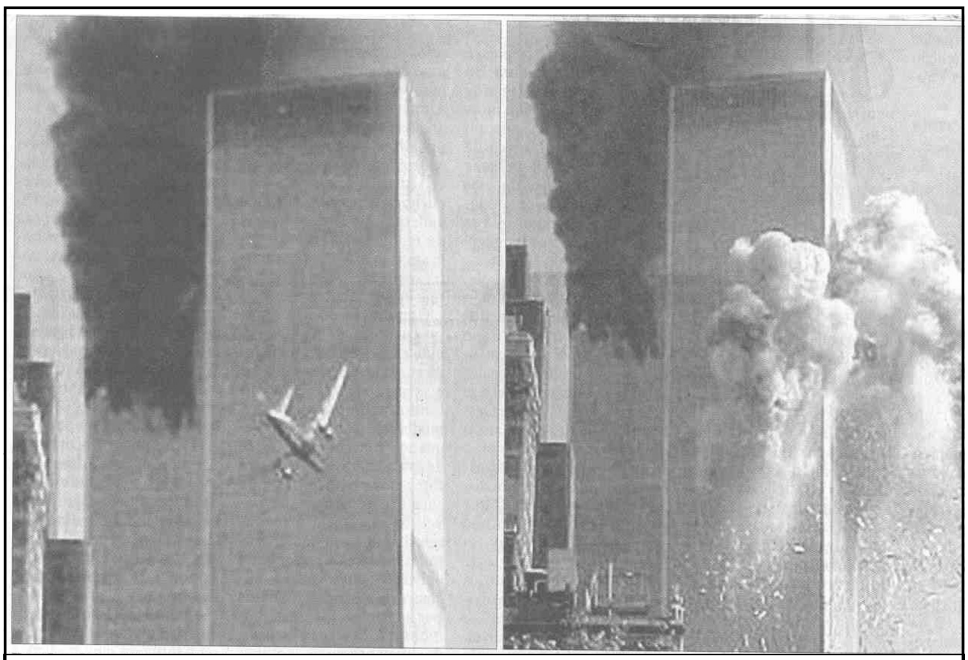

Bruno Contarini
Oscar Niemayer
Brasília Justice Office 1997
f'c = 10,500 psi (70 MPa)

5


Mário Franco
São Paulo Unique Hotel 2002
f'c = 6,000 psi (40 MPa)
Ruy Othake

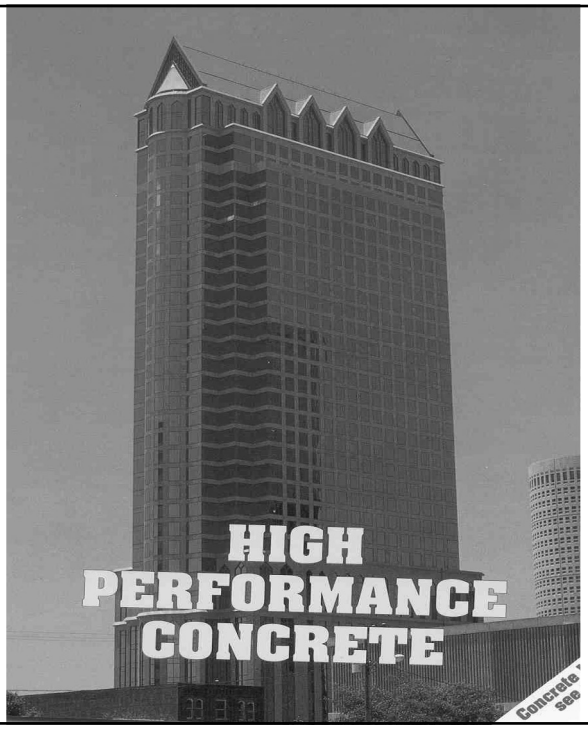
6

7

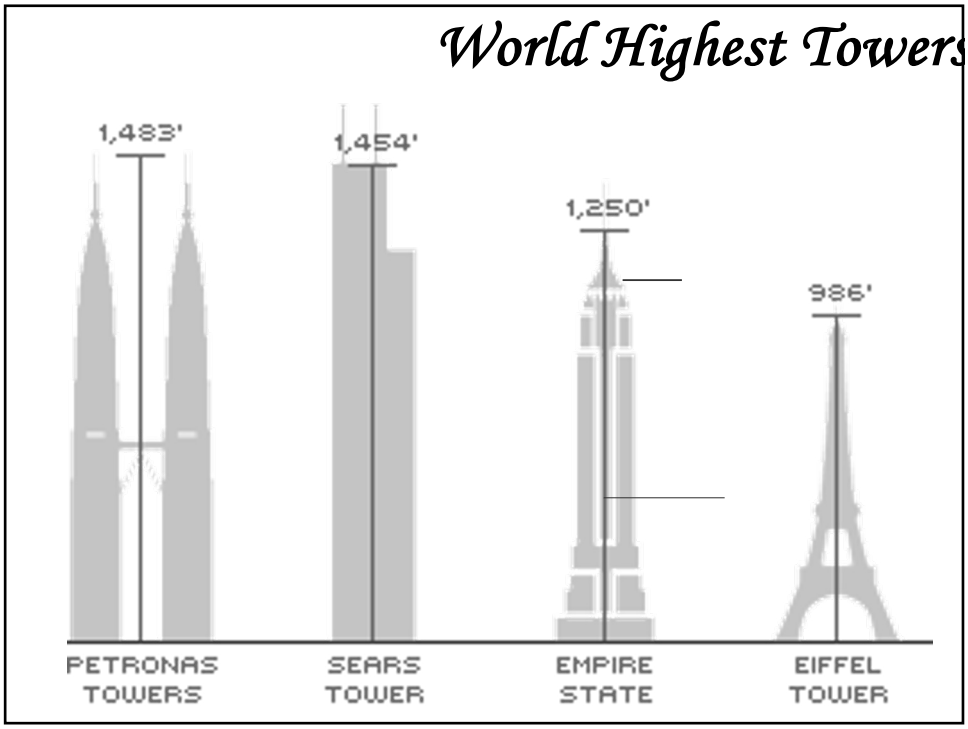


September 11, 2001

8


HIGH
PERFORMANCE
CONCRETE

9


World Highest Towers
1,483'
1,454'
1,250'
986'
PETRONAS TOWERS
SEARS TOWER
EMPIRE STATE
EIFFEL TOWER

10

Petronas Towers

Kuala Lumpur

Malásia 1999

Height 452 m

f'_c = 9,500 psi
cylinder

world record

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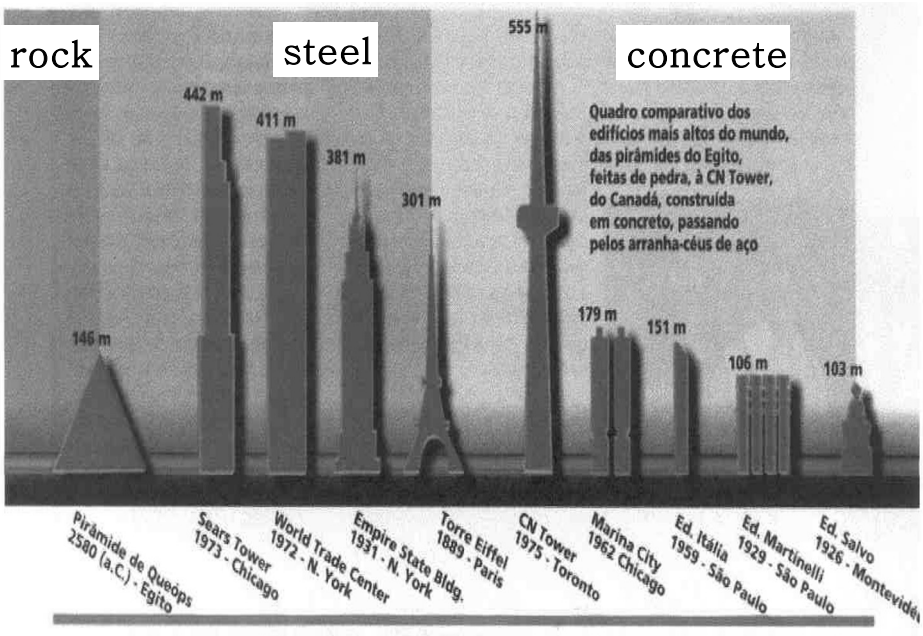
Towers



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Salvo Palace Tower

Montevideo

Uruguay 1926

Height 103 m

f'_c = ?

world record

13

The begining of skyrise buildings in the Contemporary Age was in 1890 with the Wainwright Building in Chicago, USA.

Called Chicago School

Designer
Architect Louis Henry Sullivan

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Genesis, 11.4

The God People said:

“ Let us built a City and a Tower whose top may reach unto heaven, and let us stamp our name in history before we be scattered abroad upon the face of the whole earth.”

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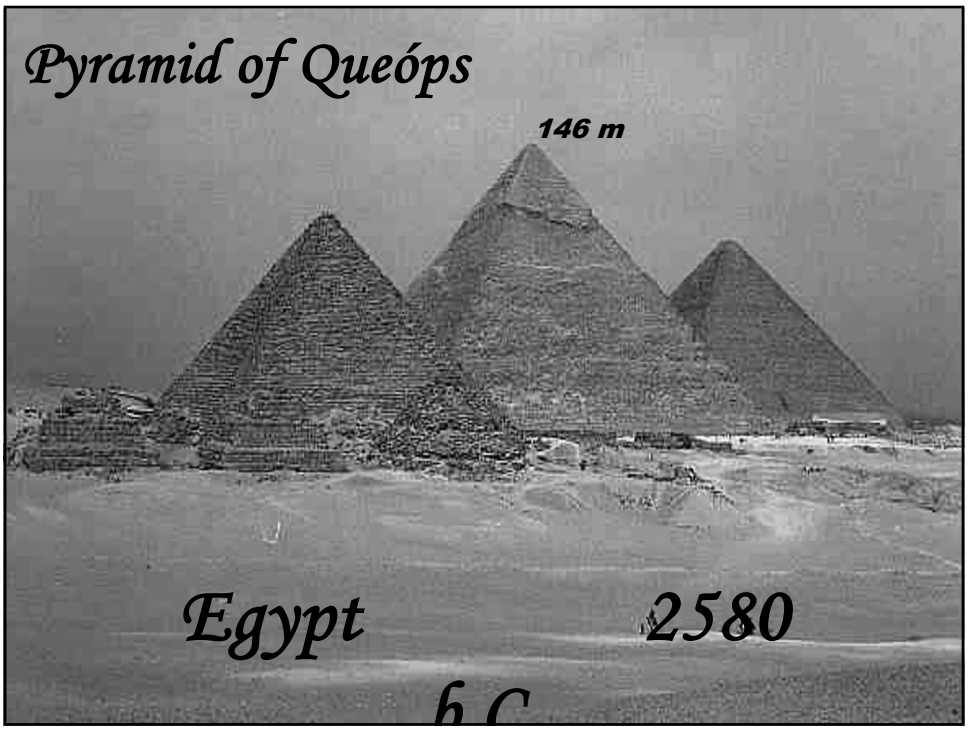
Babel Tower

Iraq 580 b.C.

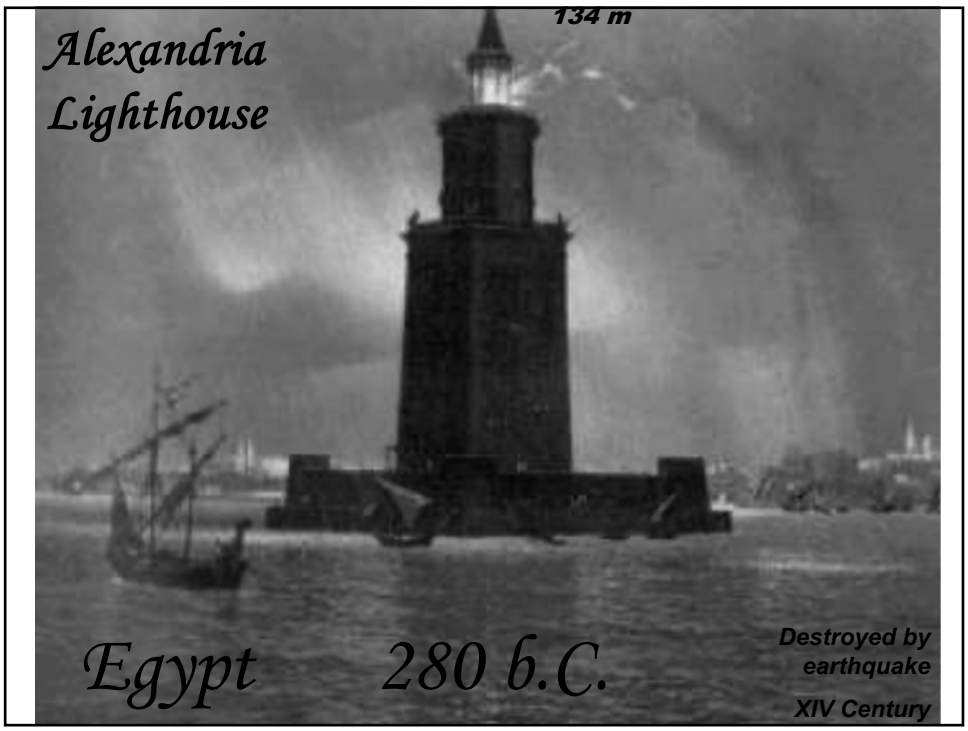
Ninrode Architect

Babylonia hanging gardens
100m columns
Nabucodonosor & Anitis

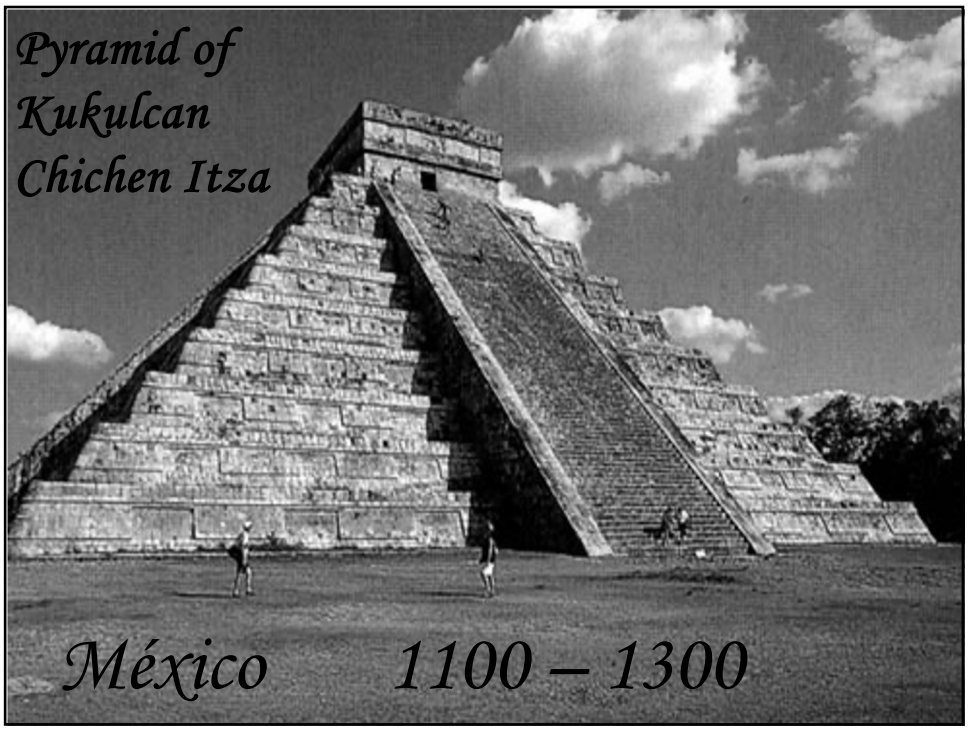
16


Pyramid of Queóps
146 m
Egypt
2580
b.C.

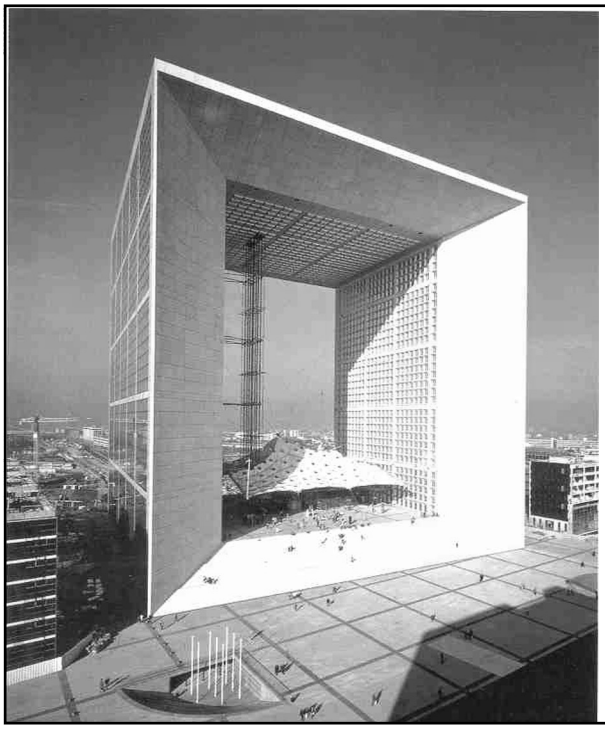
17


134 m
Alexandria
Lighthouse
Egypt
280 b.C.
Destroyed by
earthquake
XIV Century

18



19



Grand Arch

La Defense

Paris

France 1990

f'_c = 9,000 psi

"high-tech style"

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spiritual satisfaction but also achieve the actual needs

- **Structural Safety**
- **Service Life**
- **Enhanced Constructibility**
- **Reduced Cost**
- **Sustanaible Development**

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Martinelli Building

São Paulo

Brazil 1928

Height 106 m

f_{ck} = 13.5 MPa

f'_c = 2,000 psi

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Martinelli Building

f_{ck} = 13.5 MPa

f'_c = 2,000 psi

74 years old

HPC ???

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Service Life

- Carbonation
- Chlorides
- Acid ashes
- Bacteria
- Leaching
- Shrinkage
- Sulfates

- << pH
- Corrosion
- Cracks
- Spalling

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Chlorides - diffusion

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

c_{Cl} → 1 a 5 cm

$D_{ef,Cl}$ → 0,15 a 2,7 cm²/year

25

Chlorides - diffusion

e = 2,0 cm

f'_c= 15 MPa → t = 4 years

f'_c= 50 MPa → t = 150 years

f'_c= 25 MPa → t = 23 years

26

Carbonation

$$t = \frac{e^2_{co2}}{k^2_{co2}} \text{ (year)}$$

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

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Carbonation

e = 2,0 cm

f'_c= 15 MPa → t = 8 years

f'_c= 50 MPa → t = 350 years

f'_c= 25 MPa → t = 38 years

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United Nations Business Center

North Tower

São Paulo 1998

Height 179 m

f_{ck} = 50MPa

f'_c = 7,500 psi

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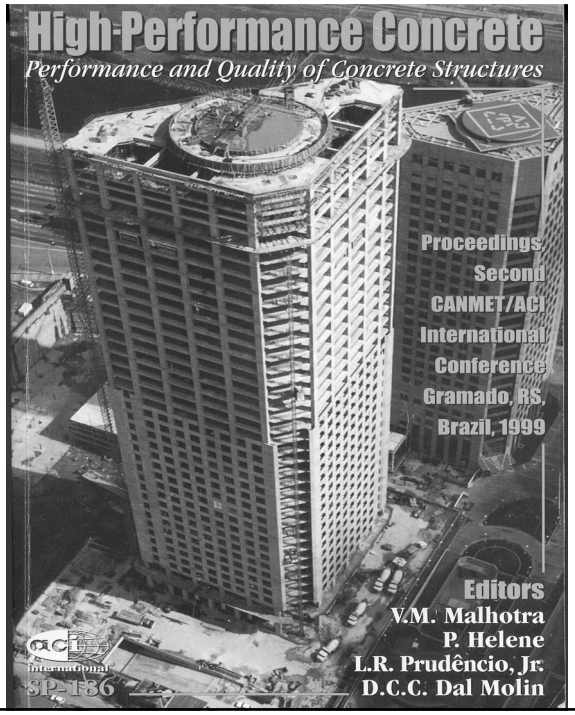
30


High-Performance Concrete
Performance and Quality of Concrete Structures
Proceedings,
Second
CANMET/ACI
International
Conference
Gramado, RS,
Brazil, 1999
Editors
V.M. Malhotra
P. Helene
L.R. Prudêncio, Jr.
D.C.C. Dal Molin
SP-186

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PLAZA CONTINENTAL SQUARE
São Paulo Brasil

- **Five Star Hotel**
- **Apart Hotel**
- **Office Tower**
- **Gym**

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Plaza Continental Square

height 100m

12 months 34,000 m^3

columns f'_c = 7,500 psi

slabs and beams f'_c = 5,500 psi

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Why High Performance Concrete?

comparing f'_c = 3,700 psi (25 MPa)

- **steel:** **- 13%**
- **concrete:** **- 19%**
- **productivity:** **- 9%**
- **structure cost:** **- 9%**

- **Save:**
  - **US $ 270,000**

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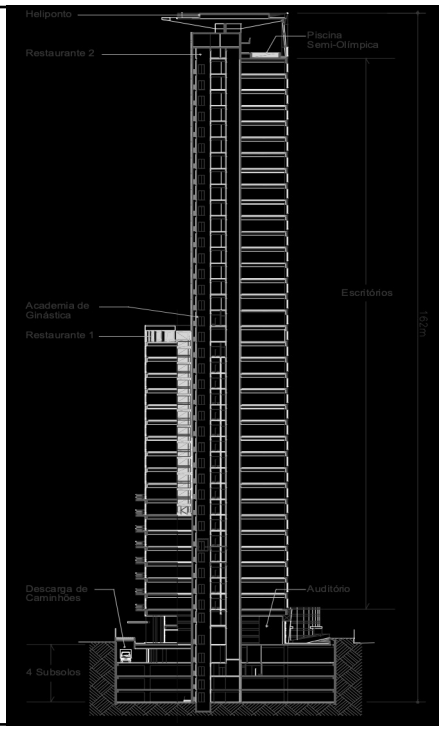
e-Tower

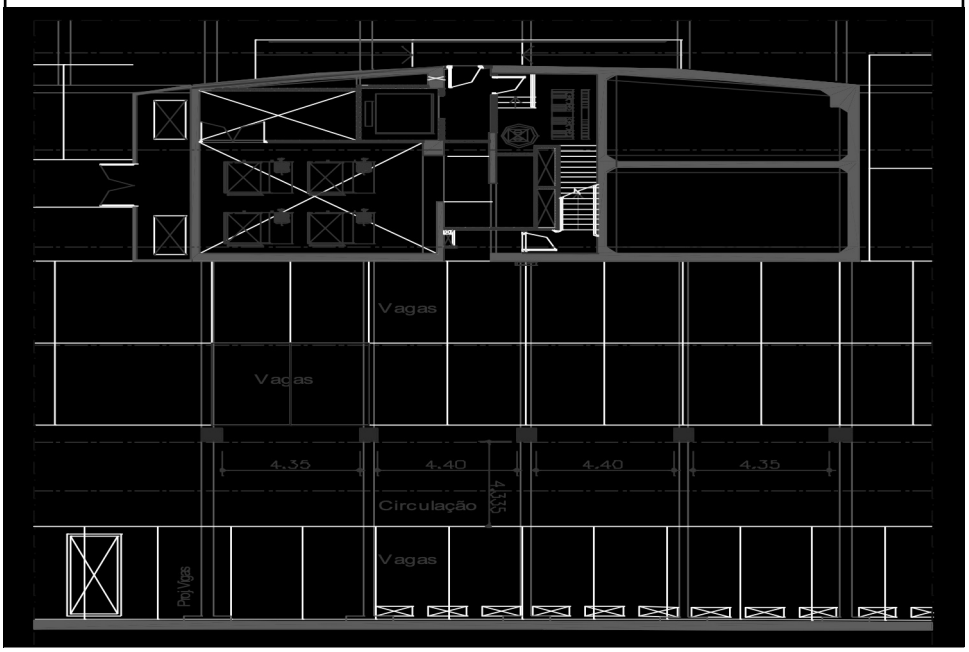
São Paulo

- 52.000 m² surface constructed
- 42 floors (04 underground)
- 800 car parking
- 02 restaurants
- Fitness center (19º floor)
- Olympic swimming pool (37º floor)



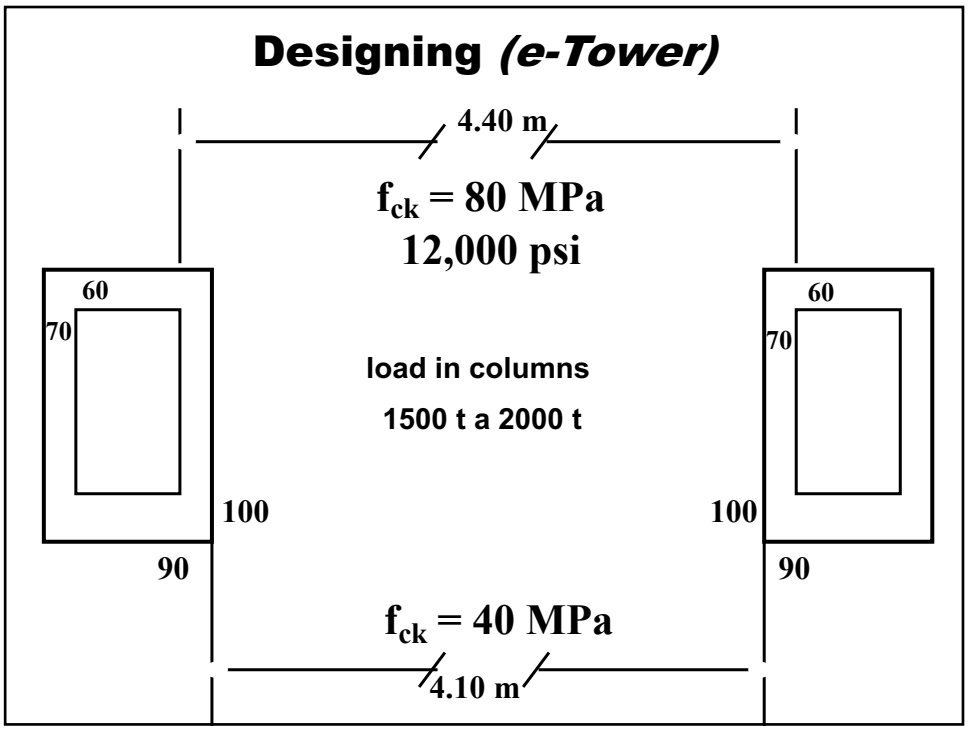
37

Designing *(e-Tower)*



38

Designing *(e-Tower)*



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Designing *(e-Tower)*

- Gain 4 additional car park by floor
- 4 x 4 floor = 16 new car park
- US $ 5,000 each car park
- earn US $ 80,000

40

Designing *(e-Tower)*

- initial cross section = 90 x 100 = 0.9 m^2
- final cross section = 60 x 70 = 0.42 m^2
- save = 0.9 – 0.42 = 0.48 m^2
- 53% less concrete volume
- cost C80 = 45% over price C40
- save 8% in concrete cost

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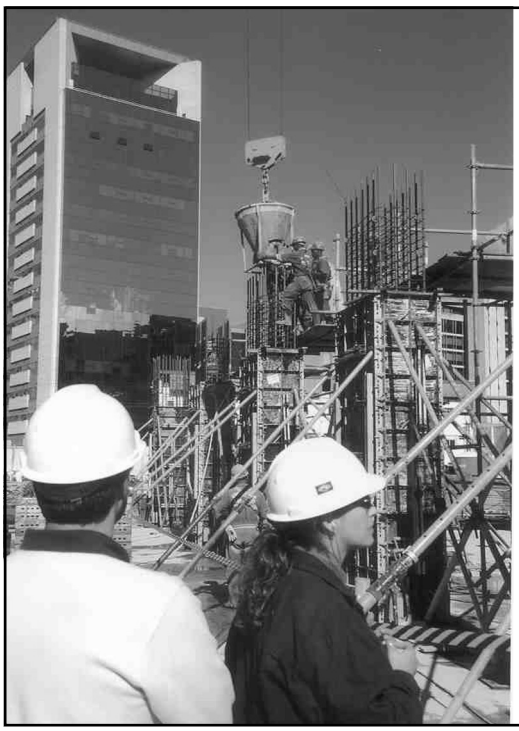

formwork

single columns

save formworks

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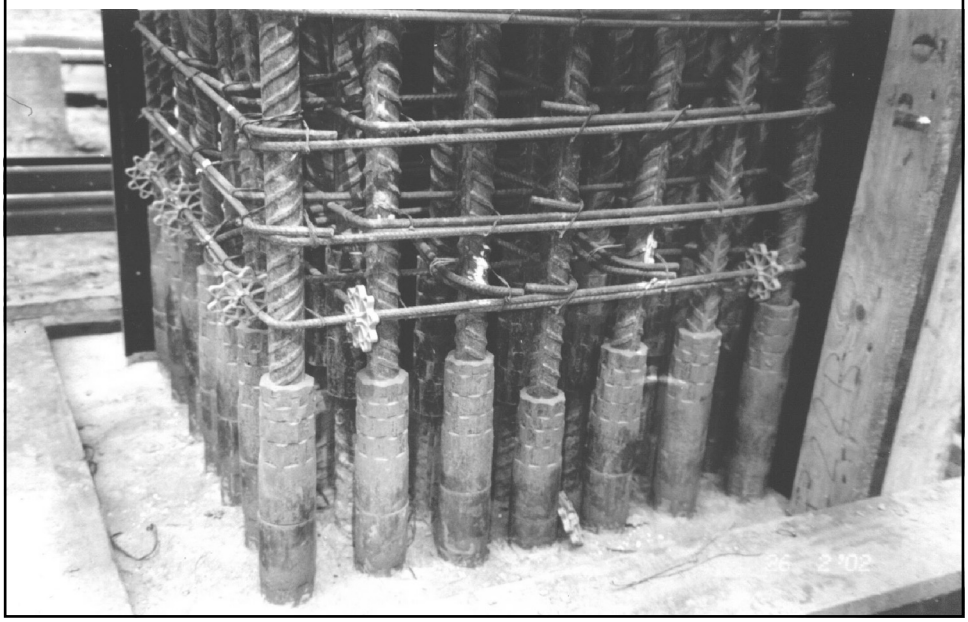
Reinforced Steel

constructibility



43

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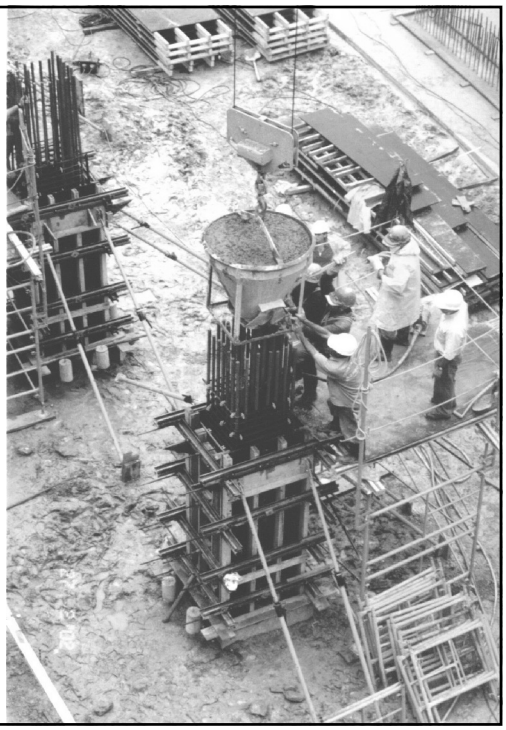
placement

- ✓ 5.5 m over reinforced steel
- ✓ no honey combs
- ✓ increasing productivity



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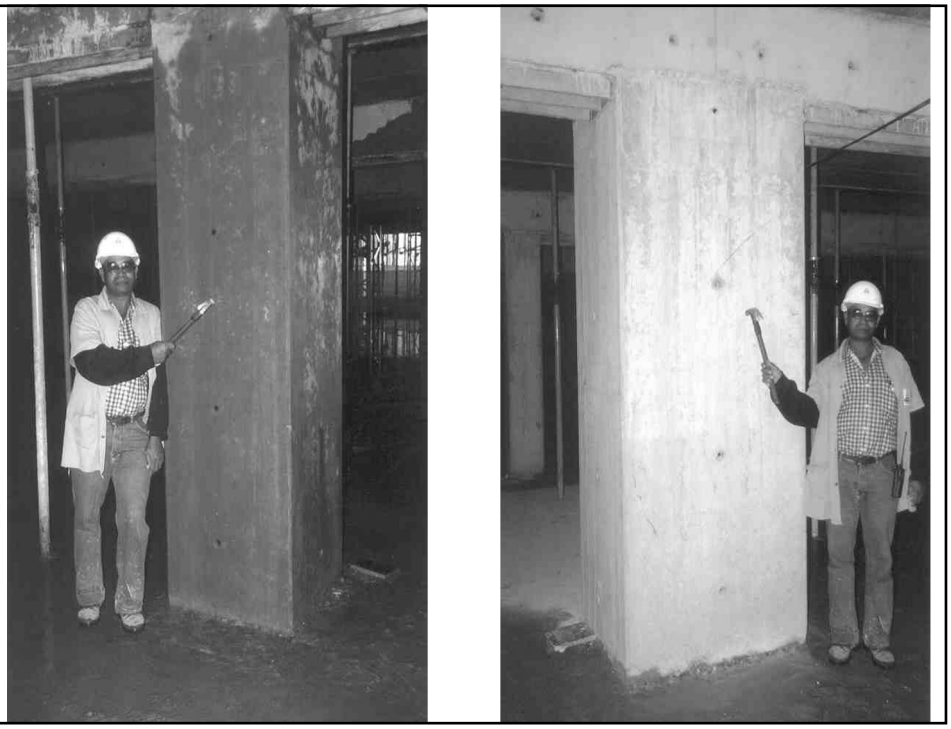

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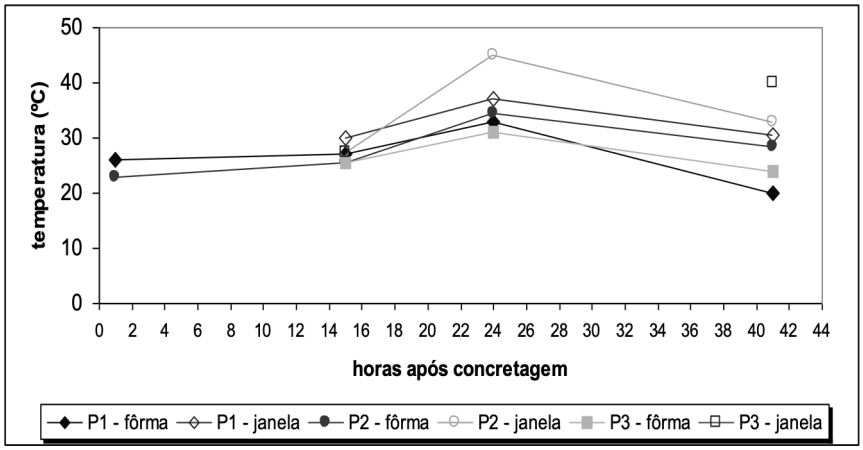
Concrete Columns Temperature



P1 = 133 P2 = 134 P3 = 135

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Concrete Mix Proportion

materials	ratio	amount	obs
blended cement	1,00	460 kg/m^3	(460 + 163 slag) CPVRS
addition	0,15	93 kg/m^3	silica & metakaolin
coarse aggregate	1,65	1.027 kg/m^3	basaltic, 19mm, MF 6,9, 3.020 kg/m^3
fine aggregate	0,88	550 kg/m^3	quartz, 2,4mm, MF 2,0, 2.670 kg/m^3
pigment	0,04	25 kg/m^3	Iron oxide
superplasticizer	0,01	6,2 kg/m^3	policarboxilato
retarder	0,0058	3,6 kg/m^3	acido hydrocarboxálico
water	0,19		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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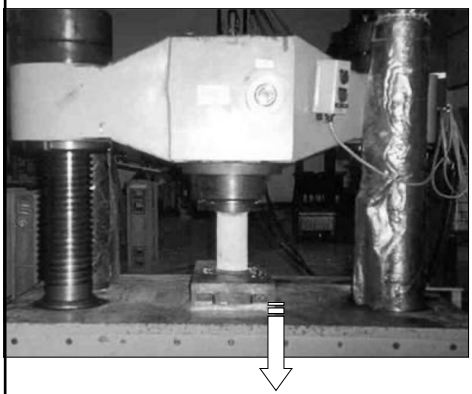
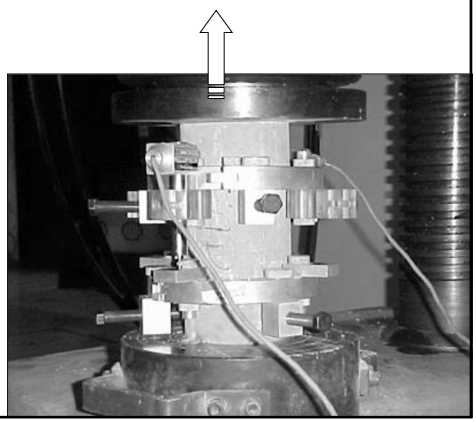
Routine Quality Control



Compression Strenght

Modulus of Elasticity



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Compression Strenght

mix	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16
Amostra	amostra 1	amostra 2	amostra 3	amostra 4	amostra 5	amostra 6	amostra 7	amostra 8	amostra 9	amostra 10
Data moldagem	10/10/2001	17/10/2001	1/11/2001	15/2/2002	27/2/2002	16/3/2002	25/3/2002	5/4/2002	11/4/2002	11/4/2002
CP 1	134.3	119.7	120.2	113.1	133.0	114.9	121.8	115.6	119.0	116.2
CP 2	131.2	123.0	124.7	121.8	144.3	105.6	127.4	114.9	129.9	126.2
CP 3	127.4	124.1	120.8	125.6	149.9	115.6	133.7	111.2	123.7	126.8
CP 4	129.9	129,6	115.8	118.7	143.0	112.4	124.9	123.1		
$f_{cmáx}$	134.3	129.6	115.8	133.1	149.9	115.6	133.7	123.1	129.9	126.8
f_{cmin}	127.4	119.7	124.7	105.6	133.0	105.6	121.8	111.2	119.0	116.2
f_{cm}	130.7	122.3	120.4	127.3	142.6	119.1	127.0	116.2	124.2	123.1
S D	2.9	2.3	3.6	3.0	3.0	2.6	2.0	3.0	2.5	3.0
C V	2.2	1.9	3.0	8.2	2.9	3.1	3.0	3.3	3.4	3.8

f'_{ca} 124.6 MPa (18,200 psi

f'_{cmin} 116.6 MPa (17,000 psi

f'_{cmax} 149.9 MPa (21,900 psi

28 days

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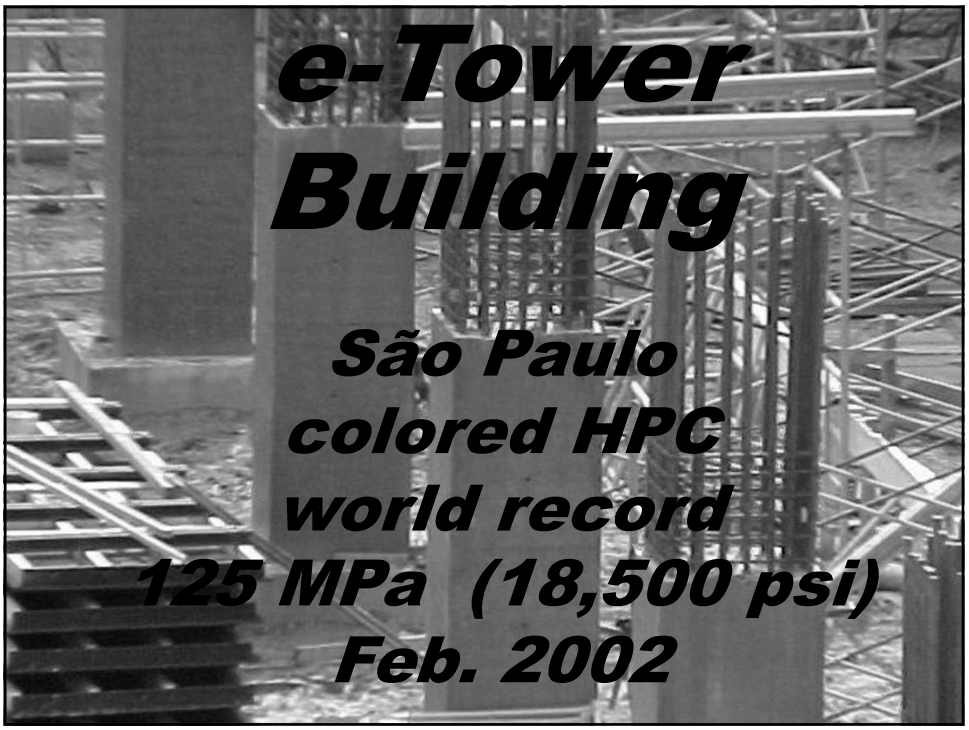
e-Tower
Building
São Paulo
colored HPC
world record
125 MPa (18,500 psi)
Feb. 2002

53

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Durability Properties

	f'_c 17,000 psi	f'_c 3,600 psi
Carbonation cabin 28+63d 25ºC 65% 5%	zero	29mm
Absorption H_2O	0,40%	7,5%
Volumn Pores	1%	17,5%
Density kg/m³	2530	2310
Capilar absorption	0,1 g/cm²	2,7 g/cm²
Capilar high	0 cm	30 cm
Chlorides	43 C	8.400 C
Abrasion cm³/cm²	0,019	0,051

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Service Life using second Fick's law for carbonation agressiveness 980 years!!!!

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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

57

The Architects and Engineers build the power landmarks of each civilization.

Translate its histories, its dreams, its ideals, in majestic and durables buildings which elevate the self esteem of his people.

58

The High Performance Concrete is one the greatest contemporary opportunity for rescue the architecture and engineering significance and vocation in all the world.

59

Acknowledgements

CONCRETO ENGEMIX

TECNUM CONSTRUTORA

Construção e Incorporação CONSTRUTORA INPAR

Master Builders Technologies

CONCRETEX

Concrete Ready Mix Company

Master Builders Technology

Metacaulim do Brasil

AKYO / Suarez construtora

GRACE CONSTRUCTION PRODUCTS

microsílica do Brasil

Método engenharia

Construction Companies

BAYER pigments

Brazilian Portland Cement Association

Escola Politécnica da Universidade de São Paulo PPCC US

60