WORKSHOP *fib* MODEL CODE 2020

Date: 29/09/2017 from 8h15 – 18h10
Venue: Milleniun Convention Center– São Paulo
Official Language: English/Portuguese with simultaneous translation.

Developments in Codes for New and Existing Concrete Structures *fib* MC2020

New Structures

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CNTU & SEESP Conselour

"do Laboratório de Pesquisa ao Canteiro de Obras"

Millenium 29 de setembro de 2017 SP / SP

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Concrete Structures Sustainability

1. Cement performance concept:

- f_{ck} = 20MPa → cement content > 12 kg/MPa
- f_{ck} = 50 MPa → cement content > 8 kg/MPa
- f_{ck} = 90 MPa → cement content > 5 kg/MPa

Material	Bauru/SP (C20)	Petronas Tower (C50)	Burj Kalifa (C80)
cement	269	400	400
silica	-	44	50
fine	912	775	830
coarse	891	1000	847
water	196	180	160
W/C	0.73	0.45	0.32
others	1.5% (admixture)	2.0% (admixture)	3.5% (admixture)

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Concrete Structures Sustainability

2. Control age concept:

f_{ck} at 63 days → cement content can reduce:

- for f_{ck} = 20MPa → 16 kg less cement/m^3
- for f_{ck} = 50 MPa → 26 kg less cement/m^3
- for f_{ck} = 90 MPa → 30 kg less cement/m^3

The Burj Dubai project
✓ E_c = 44 GPa at 91 days
Concrete cube strengths at 56 days:
✓ Mat slab: SCC 6000 psi → SCC 35 MPa
✓ Core walls and columns: 11,600 psi → 65 MPa

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Concrete Structures Durability

Durability Limit State (DLS) concept:

Carbonation (*deterministic approach*):

- ***No risk and no DSL for water satured concrete***
- ***No risk and no DLS for Dry Environmental RH < 70% and superficial concrete humidity < 5%***

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Concrete Structures Durability

Durability Limit State (DLS) concept:

Carbonation (*deterministic approach*):

- *For wet environmental (and dry and wet)*

  70% < RH < 95% and superficial concrete humidity > 5%
- Model for Service Life Design preview: $\mathbf{c_{CO_2}} = \boldsymbol{k_{CO_2}} * \sqrt{t}$
- DLS: carbonation deep (c_{CO_2}) = concrete cover (c)
- t → service life target in years
- $\boldsymbol{k_{CO_2}}$ → carbonation coefficient in mm/$\sqrt{year}$
- Valid for all agressiveness environmental class

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Concrete Structures Durability

Durability Limit State (DLS) concept:

Reference carbonation coefficients:

f_{ck}	k_{CO_2} in mm/$\sqrt{year}$
20	3.55
25	3.15
30	2.85
35	2.45
40	2.10
45	1.35
50 to 90	0.45

Notes:

1. For concretes with slag, fly-ash, microsilica and metacaulim, increase 20% in $\boldsymbol{k_{CO_2}}$ values;
2. Deterministic approach means at the end of service life, 50% exposed reinforcement could be no passivated

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Concrete Strength Control

Comparing

ABNT NBR 6118 / NBR 12655

ACI 318

EN (*fib*) 206

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Summary - frequency of control

<table>
<tr><td>ABNT NBR 12655</td><td colspan="2">• every 8m³!!</td></tr>
<tr><td>ACI 318-14</td><td colspan="2">• ≥ once a day concreted;
• ≥ once per 115 m³ of concrete;
• ≥ once per 465 m² of slabs or walls;
• dispensed the control for volumes <38m³</td></tr>
<tr><td rowspan="3">EN 206-1:2013</td><td colspan="2">• ≥ 3 samples in the first 50m³;</td></tr>
<tr><td>Initial production (until at least 35 test results are obtained)</td><td>• ≥ 1 per 200 m³ or 1 per 3 production days (concrete with production control certification)
• ≥ 1 per 150 m³ or 1 per production day (concrete without production control certification)</td></tr>
<tr><td>Continuous production (when at least 35 test results are available)</td><td>• ≥ 1 per 400 m³ or 1 per 5 production days or 1 per calendar month (concrete with production control certification)
• ≥ 1 per 150 m³ or 1 per production day (concrete without production control certification)</td></tr>
</table>

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Summary - conformity criteria

ABNT NBR 12655	• $f_{ck,est} \geq f_{ck}$
ACI 318-14	• $f_{ci} \geq f_{ck} - 3.5$MPa para $f_{ck} < 35$MPa • $f_{ci} \geq 0.9*f_{ck}$ para $f_{ck} > 35$MPa • $f_{cm3,est} \geq f_{ck}$
EN 206-1:2013	• $f_{ci} \geq f_{ck} - 4$; • $f_{cm,3,est} \geq f_{ck} + 4$ • $f_{cm,15,est} \geq f_{ck} + 1.48 *\sigma$

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Concrete Strength in Existing Structures

1. Correct the compressive strength of the concrete cores using only the form coefficients (0.82 to 1.00), the extraction / placement direction (1.05), the core damage (1.06) and the humidity [saturated (1.00); environment (0.95); dry (0.90)]. Result: $f_{ck,eq}$ = 0.86 a 1.11*$f_{c,core}$
2. Disregard the effects of growth (hydration), the decrease by sustained load, the decrease by insufficient consolidation and the decrease due to inadequate cure, considering included;

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Concrete Strength in Existing Structures

3. Adopt as $f_{ck,eq}$ the value obtained at the test date. (***fib*** Bulletin 80 and ACI 318)

Bulletin *fib* 80 Pág. 37

4.1.6 Estimation of characteristic values and treatment of statistical uncertainties

...EN 1990:2002 provides guidance on estimating characteristic values of material properties based on small samples. *If the characteristic strength values for existing structures are determined based on test samples, time-dependent and environmental effects can be considered as inherently included.* However shape effect and the damage effect introduced by the extraction of test material are still to be included through a conversion factor...

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ACI 318-14 Building Code Requirements for Structural Concrete and Commentary. 2015. 520p.

Chapter 26. Construction Documents and Inspection.

R26.12.4.1(d) An average core strength of 85 percent

dation, and curing conditions. The acceptance criteria for core strengths have been established with consideration that cores for investigating low strength-test results will typically be extracted at an age later than specified for f_c'. For the purpose of satisfying 26.12.4.1(d), this Code does not intend that core strengths be adjusted for the age of the cores.

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Concrete Strength in Existing Structures

3.

4. On the security check, whenever the geometry, dimensions, plumb line, level, orthogonal and the position and reinforcement ratio are correct, use γ_c = 1.31 and γ_s = 1.05

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According to *fib* MC2010 the partial factor γ_M is obtained as the following product:

$\gamma_M = \gamma_{Rd} * \gamma_m = \gamma_{Rd1} * \gamma_{Rd2} * \gamma_m$

where γ_{Rd1} denotes the partial factor accounting for model uncertainties, γ_{Rd2} is the partial factor accounting for geometrical uncertainties and γ_m is the partial factor accounting for variability of the material and statistical uncertainties.

The partial factors related to the model and geometrical uncertainties for concrete:

γ_{Rd} = 1.05 * 1.05 = 1.10 for new structures

γ_{Rd} = 1.05 * 1.00 = 1.05 for existing structures

$\gamma_C = \gamma_{Rd} * \gamma_m = \gamma_{Rd1} * \gamma_{Rd2} * \gamma_c$ = 1.5 for new structures

$\gamma_C = \gamma_{Rd} * \gamma_m = \gamma_{Rd1} * 1.00 * 0.9 * \gamma_c$ = 1.31 for existing (well build) structures

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Building in SP

Built between 1957 and 1960

ABNT NB1:1950

f_{ck} = 13 MPa

1959

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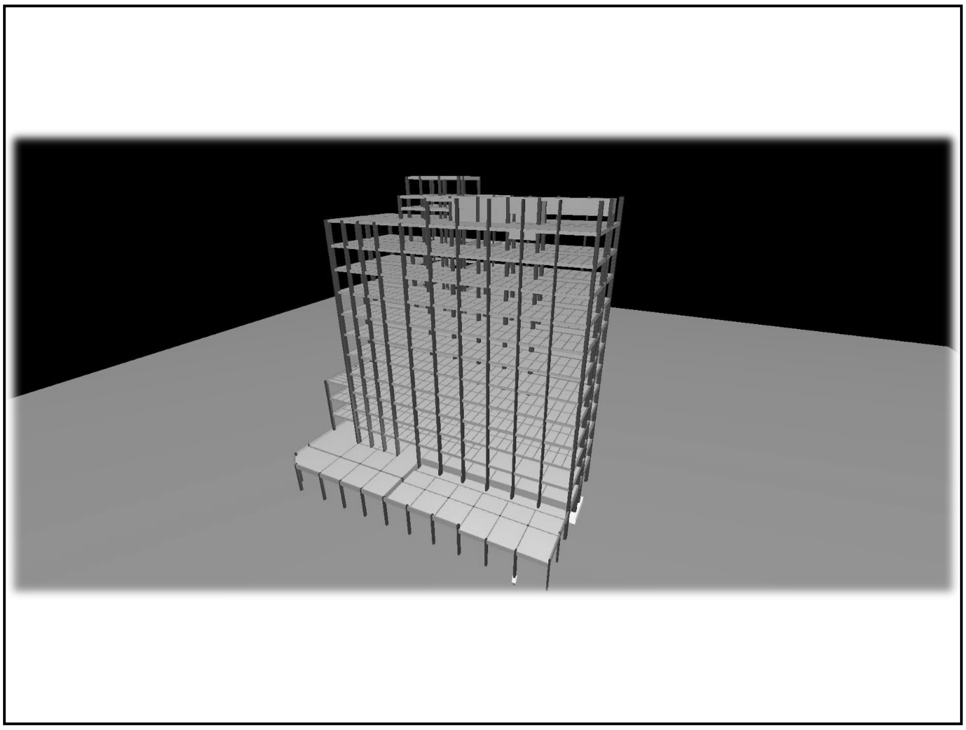

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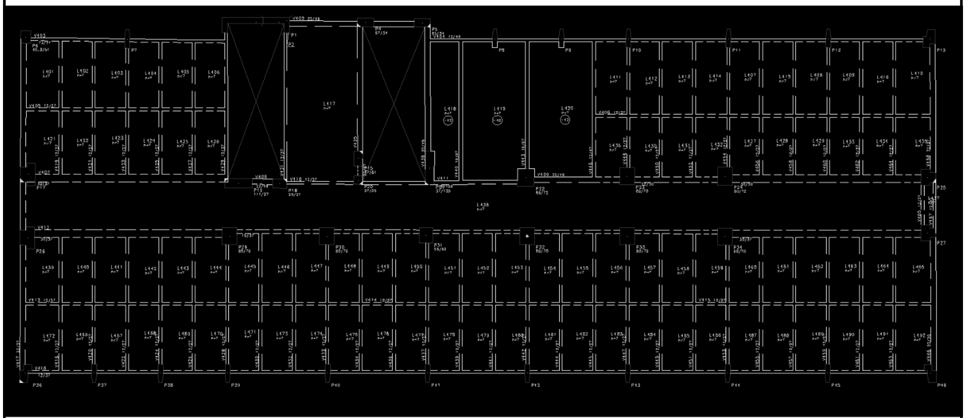
Floor type



nº Columns (type): 46
nº of beams (type): 68

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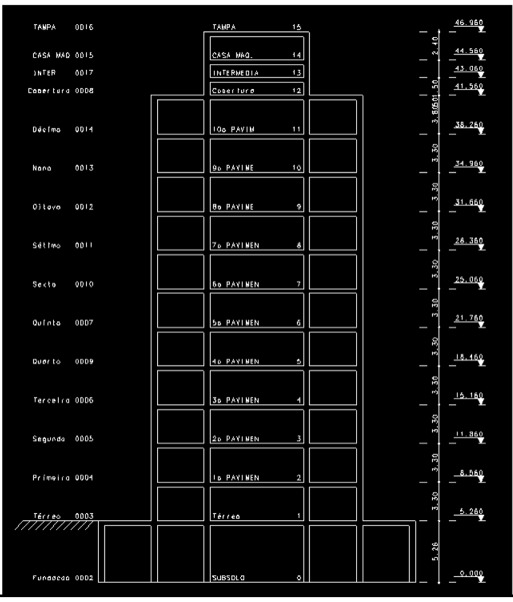
Schematic cross



1 Underground
1 Ground floor
10 Floor type
1 Cover slab
1 Machine House
1 Helipad

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Results of cores samples after 50 years

Cores made on 80 columns of a total of 460 columns of the Tower (~ 17% of the total)

Cores in 6 beams / slabs (Ground & Underground)

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Results of cores samples after 50 years

Corrections adopted:

test → $f_{ck,eq} = 1.06 * 1.05 * f_{c,ext}$

Reduction of γ_C from 1.50 to 1.31

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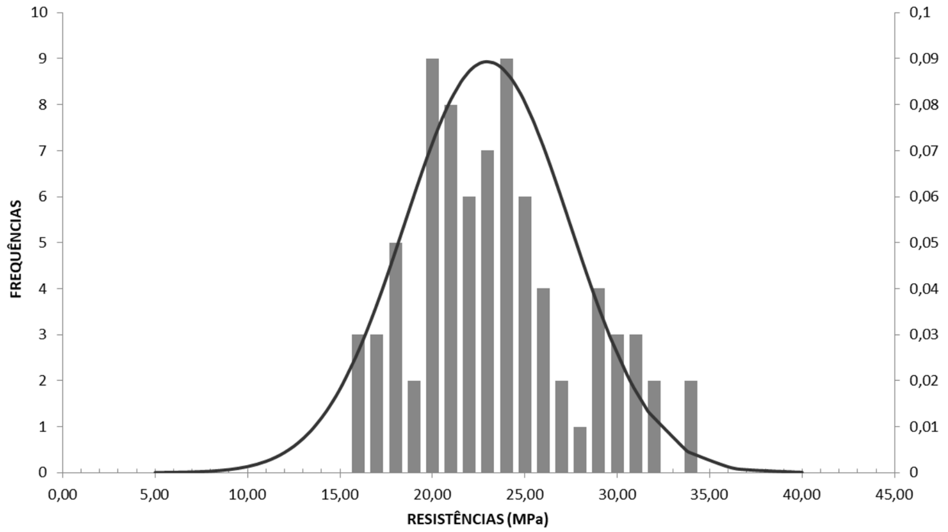
Cores
NORMAL DISTRIBUTION



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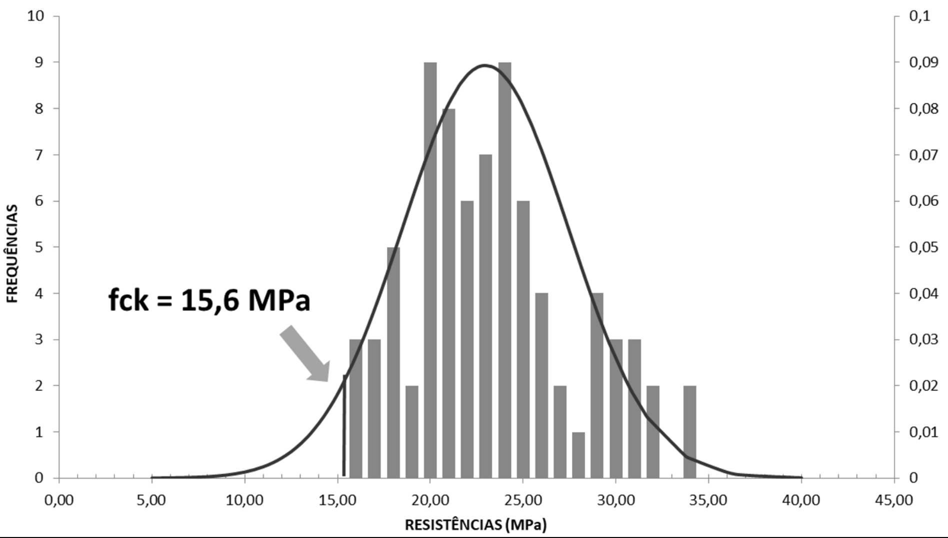
Cores
NORMAL DISTRIBUTION



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Assessment before Retrofit

- ***Same structural model of concrete structure used in 1958;***
- ***Evaluation by NB-1 1978 with some criteria from ABNT NBR 6118:2003, including fire design;***
- ***Results indicate the need to strengthening 2 columns and 4 beams, besides to increase 2 cm in the thickness of all slabs and beams to protect against fire.***

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