¿Puede el diseño estructural contribuir a la sostenibilidad?

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ASOCIACIÓN ARGENTINA
DE TECNOLOGÍA DEL
HORMIGÓN

Introducción de la Seguridad y Sostenibilidad en el Diseño de las Estructuras de Concreto, según el ***fib*** Model Code- 2024; Eurocode II-2023 y ACI 318-2019/22

Colaboradores: Ing. Ricardo Boni, mestrando do IPT, & Ing. Rafael Silva, ambos del equipo PhD

… ¿cómo los ingenieros diseñan las estructuras, edificios, puentes, para quedaren parados, bajo las enormes fuerzas de la naturaleza: la gravedad, los vientos, las vibraciones, las inundaciones, los huracanes, los sismos y el fuego???

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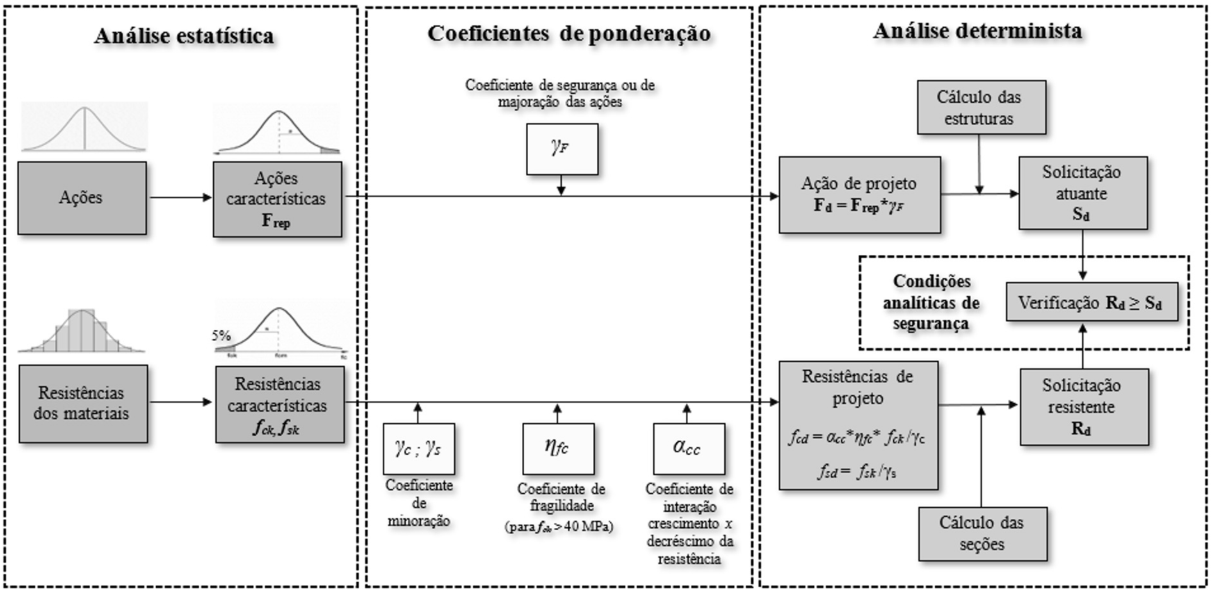
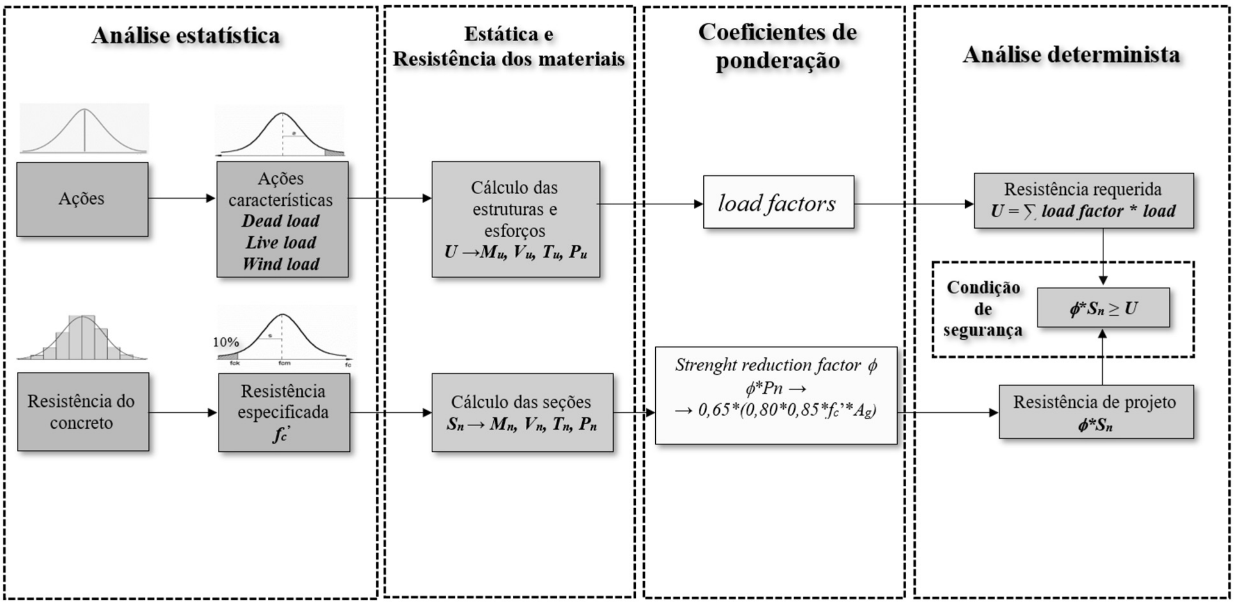
acciones y materiales en las estructuras de concreto

Método semi probabilista – Partial factor format – fib Model Code 2020



acciones y materiales en las estructuras de concreto
ACI 318 (2019/2022)



Análise estatística

Ações

Ações características
Dead load
Live load
Wind load

Resistência do concreto

Resistência especificada
f_c'

Estática e Resistência dos materiais

Cálculo das estruturas e esforços
$U \rightarrow M_u, V_u, T_u, P_u$

Cálculo das seções
$S_n \rightarrow M_n, V_n, T_n, P_n$

Coeficientes de ponderação

load factors

Strenght reduction factor ϕ
ϕ*Pn →
→ 0,65*(0,80*0,85*f_c'*A_g)

Análise determinista

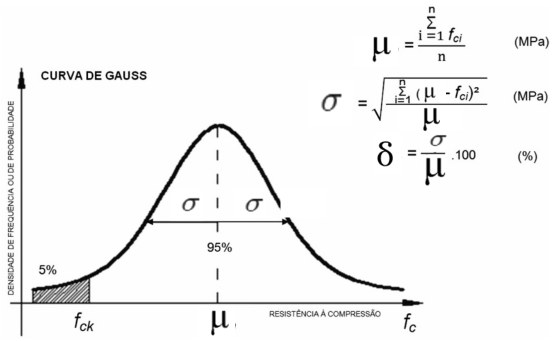
Resistência requerida
$U = \sum$ ***load factor * load***

Condição de segurança

$\phi * S_n \geq U$

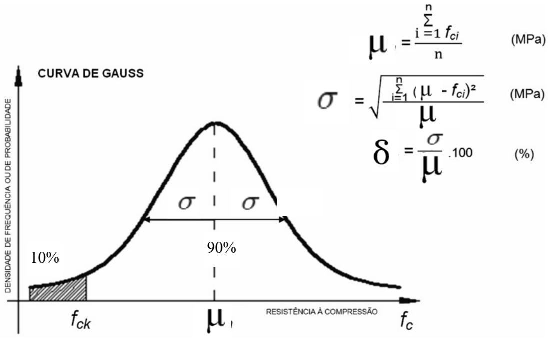
Resistência de projeto
$\phi * S_n$

…¿qué es la resistencia especificada (o característica) del concreto a la compresión, *f'c*?



MC 2020 resistencia característica *f_{ck}*

ACI 318 resistencia especificada *f'_c*



¿cuál es la referencia para el diseño estructural y aceptación de la resistencia a la compresión del concreto, f'_c en Argentina ?

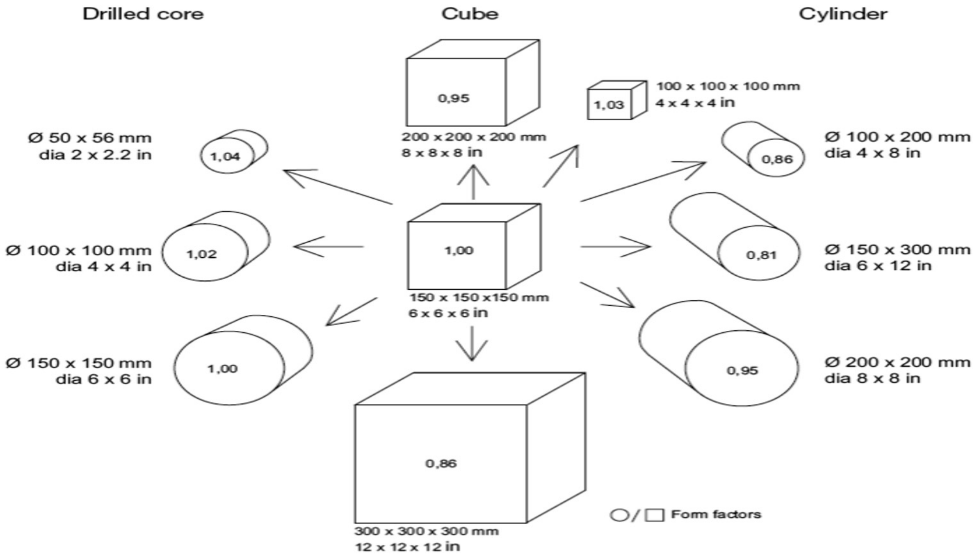


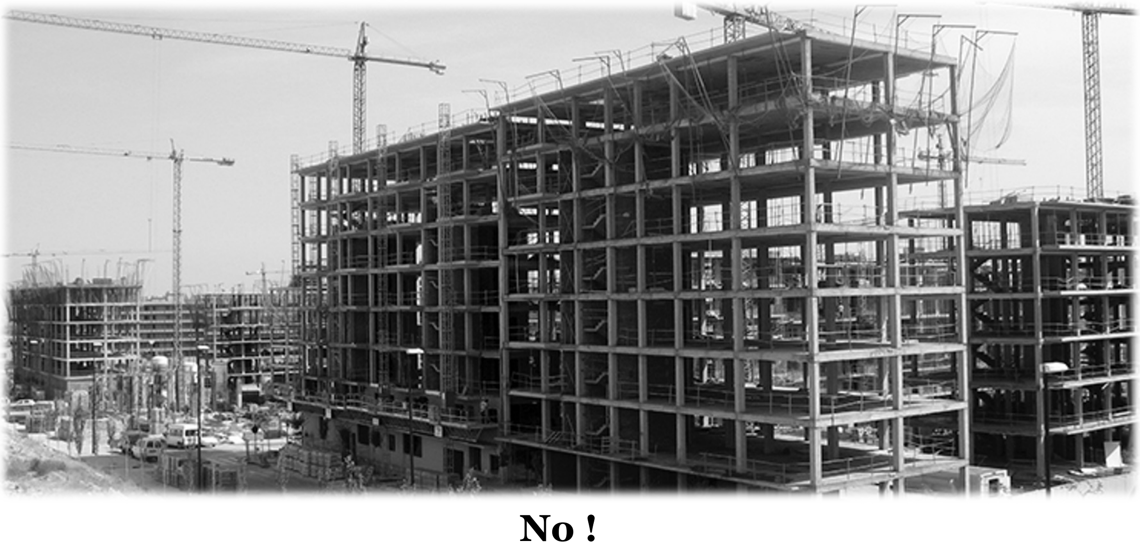
Figure 7-21 Form factors

referencial en ARGENTINA (CIRSOC?)
de resistencia a la compresión del concreto, f'_c

- ✓ **el cilindro 15cm ϕ * 30cm**
- ✓ **el cilindro 10cm ϕ * 20cm**
- ✓ **muestreo planeado**
- ✓ **bien moldeado**
- ✓ **bien compactado**
- ✓ **curado UR > 95%**
- ✓ **bien terminado y acabado en los topos**
- ✓ **ensayado carga axial monotónica y rápida**

referido a una cierta edad

¿f'_c es la resistencia del concreto en la estructura?



No !

f'_c es la resistencia potencial del concreto en
la boca de la hormigonera !

f'_c
es la resistencia del concreto en la cimentación, pilotes, columnas, vigas y losas de la estructura?

No !
f'_c es la resistencia potencial del concreto de la mezcla de esa hormigonera, medida através de probetas patrón moldeadas e ensayadas en condiciones ideales!

f'_c
es la resistencia del concreto de partida que el proyectista estructural utiliza para dimensionar y verificar la seguridad?

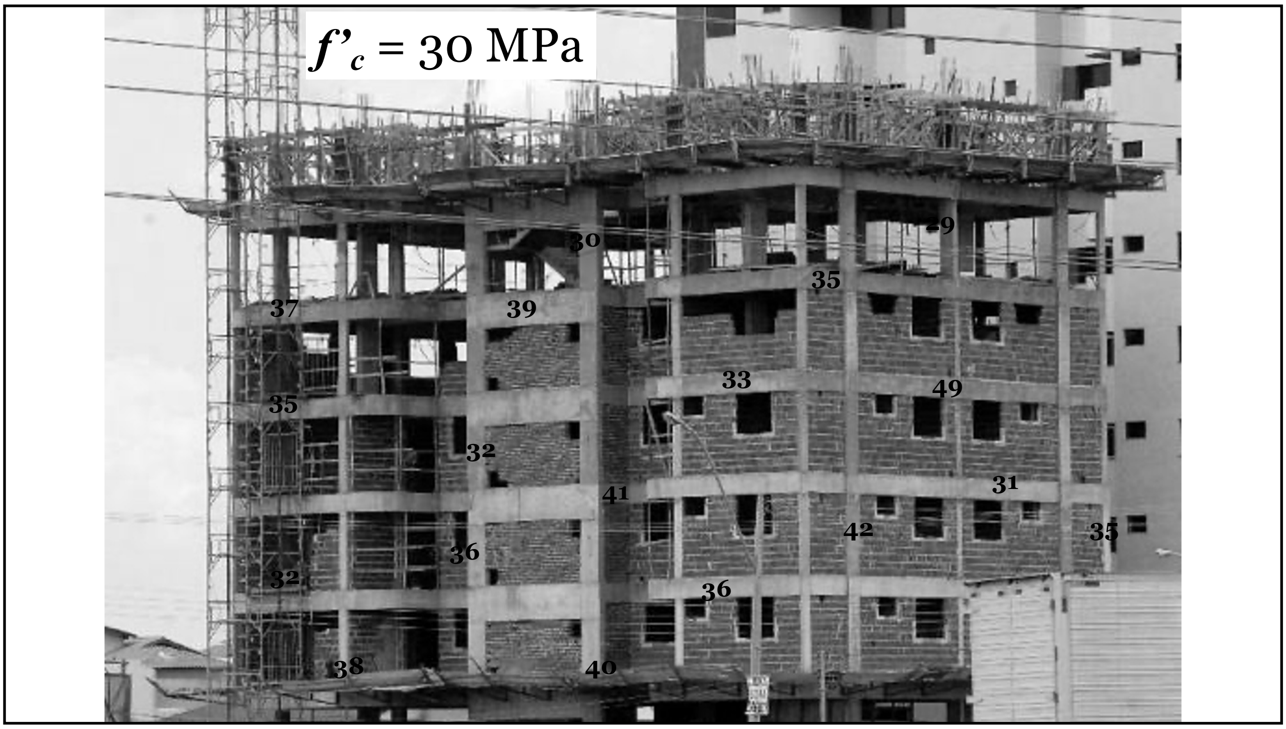
Si !
f'_c es la resistencia especificada del concreto a la compresión utilizada como valor de entrada en los programas de dimensionamiento y verificación de la seguridad de estructuras !

… y ese es un gran problema porque algunos ingenieros y diseñadores consideran que *f'c*
es la resistencia del hormigón que hay en la estructura !..

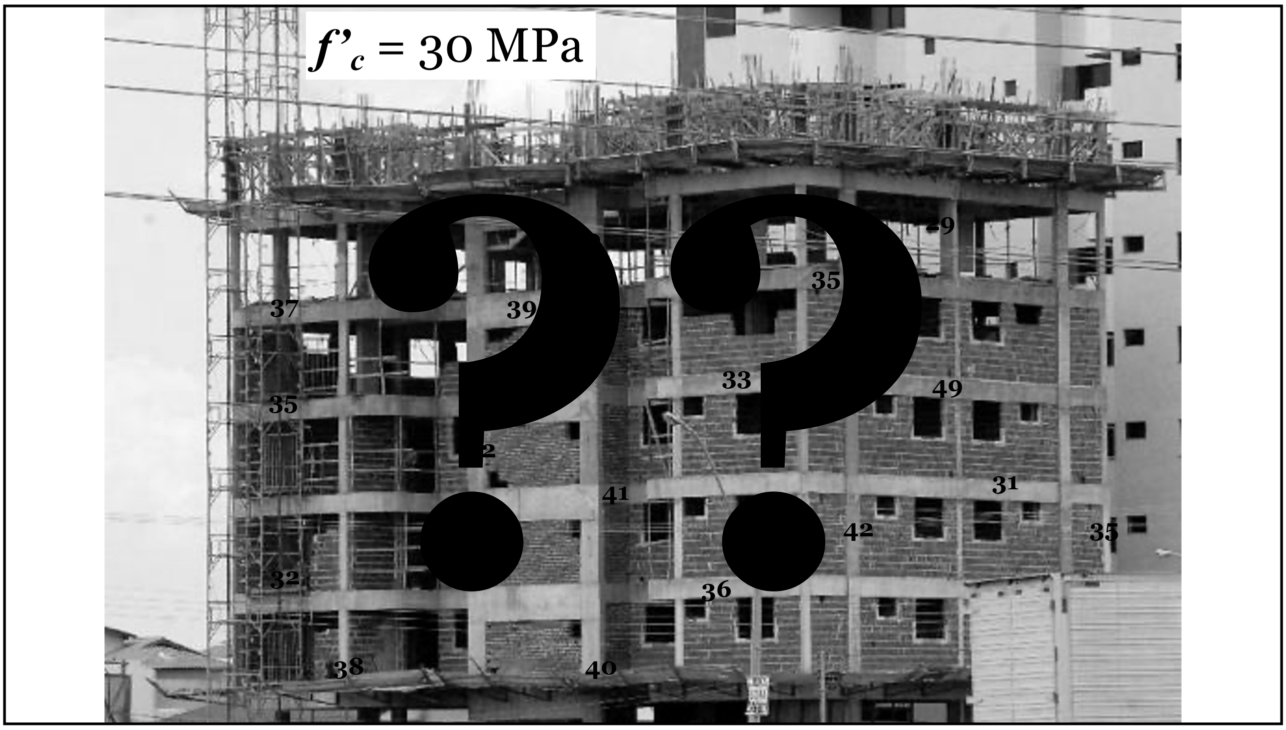
15

… entonces, ¿cuál es la resistencia a la compresión "mínima" del concreto en la estructura que un ingeniero civil puede considerar como disponible para fines de diseño y construcción, de manera segura, durante su VUP ?…

16

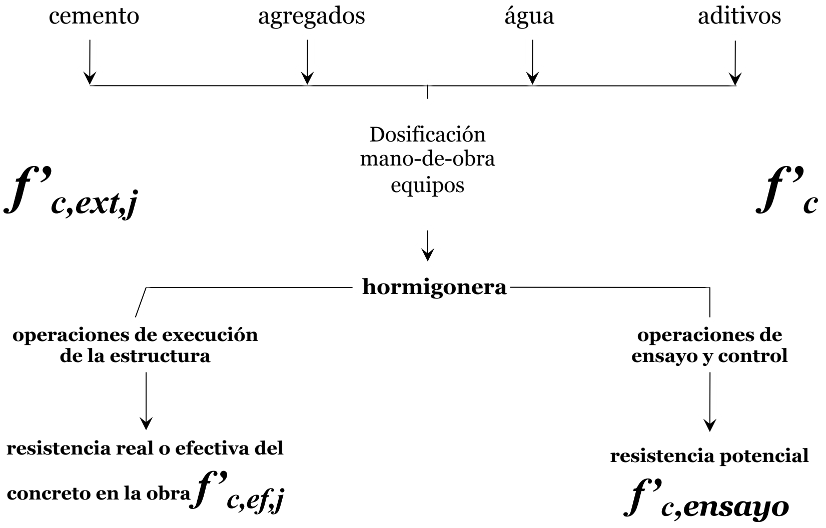


$f'_c = 30$ MPa



$f'_c = 30$ MPa

resistencia del concreto



cemento

agregados

ágüa

aditivos

Dosificación
mano-de-obra
equipos

$f'_{c,ext,j}$

f'_c

hormigonera

operaciones de execución de la estructura

resistencia real o efectiva del concreto en la obra $f'_{c,ef,j}$

operaciones de ensayo y control

resistencia potencial $f'_{c,ensayo}$

Referencial de Diseño y Construcción

ACI 318 → $f'_c \sim f_{ck}$

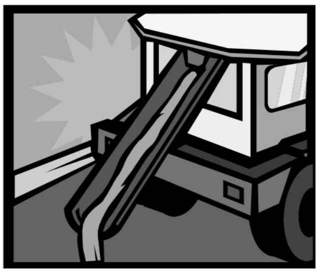
ACI 214 → $f'_{c,control}$

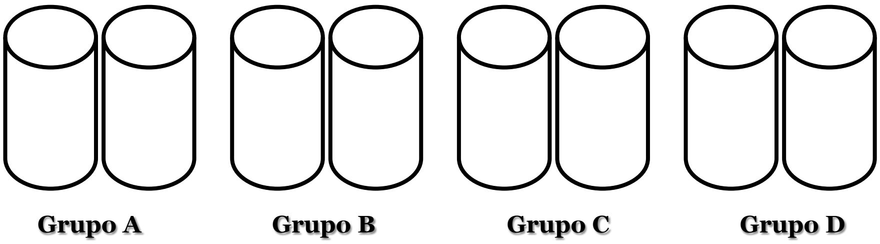
ACI 214 y ACI 437 → $f'_{c,ext,j}$

…¿ cómo obtener la mayor resistencia a compresión, f'_c a cierta edad?

Concreto de una mezcla bien hecha:

puede moldear, curar y tratar a gusto !

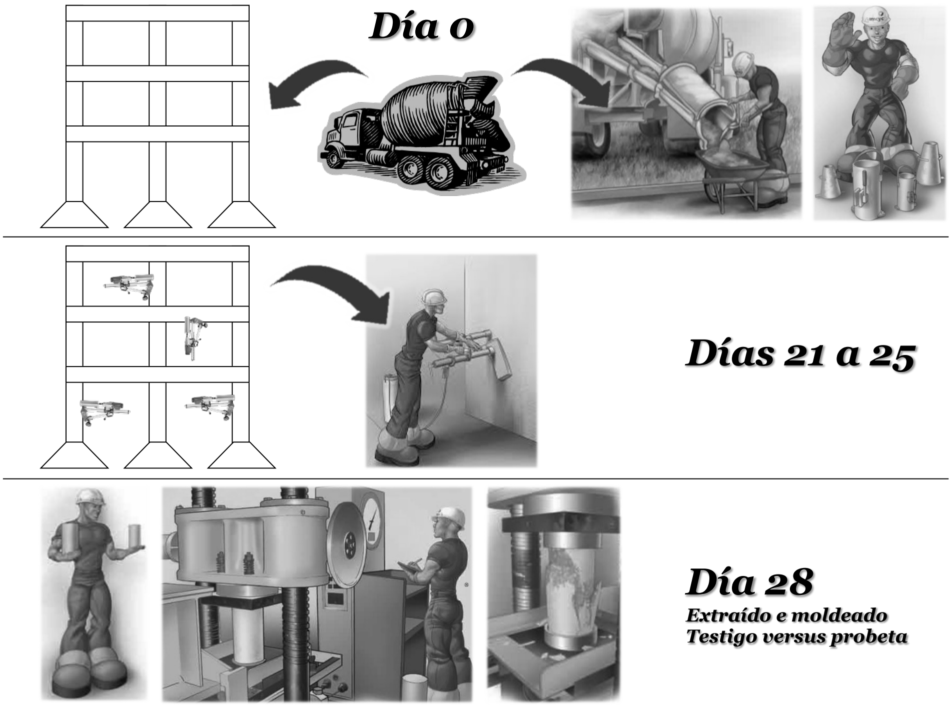




TESIS de DOCTORADO

CREMONINI, R. A. Análise de Estruturas Acabadas: Contribuição para a Determinação da Relação entre as Resistências Potencial e Efetiva do Concreto. São Paulo, EPUSP, 1994.

Ruy Alberto Cremonini. Prof. Associado, UFRGS



Día 0

Días 21 a 25

Día 28

Extraído e moldeado
Testigo versus probeta

Conclusiones

pilares/columnas:

$$\eta = \frac{f_c}{f_{c,ext}} = \frac{f_{ck}}{f_{ck,ext}} = 1.24$$

losas & vigas

$$\eta = \frac{f_c}{f_{c,ext}} = \frac{f_{ck}}{f_{ck,ext}} = 1.20$$

resistencia de "calculo/diseño" del concreto

MC 2020 & EN 1992-1-1

α_{cc}= 0,85 a 1,00

$$\boxed{f_{cd} = \alpha_{cc} * \eta_{fc} * \frac{f_{ck}}{\gamma_c}}$$

$$\eta_{fc} = \left(\frac{40}{f_{ck}}\right)^{1/3} \leq 1{,}0\ MPa$$

para f_{ck} = 30 MPa

$$f_{cd} = 0{,}85 * 1 * \frac{30}{1{,}5}$$

$f_{ck,ef}$ (estrutura) ≈ 17 MPa

para f_{ck} = 50 MPa

$$f_{cd} = 0{,}85 * \left(\frac{40}{50}\right)^{0{,}33} * \frac{50}{1{,}5}$$

$f_{ck,ef}$ (estrutura) ≈ 26 MPa

edificaciones
ABNT NBR 6118

$$f_{cd} = \alpha_{cc} * \eta_{fc} * \frac{f_{ck}}{\gamma_c}$$

$$f_{cd} = 0{,}85 * 1 * \frac{f_{ck}}{1{,}4}$$

$$f_{cd} \cong 0{,}61 * f_{ck}$$

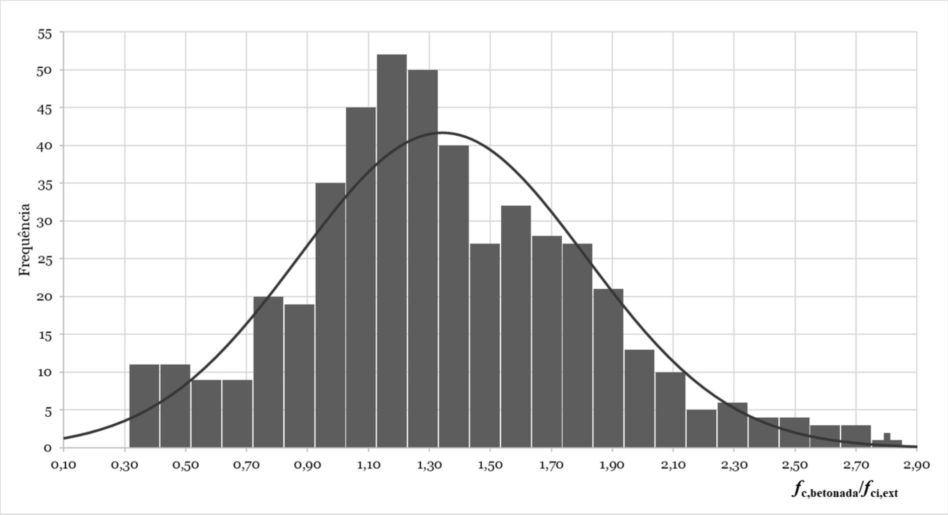
estaca hélice
pilote de fundación
ABNT NBR 6122

$$f_{cd} = 0{,}85 * \frac{f_{ck}}{\gamma_c}$$

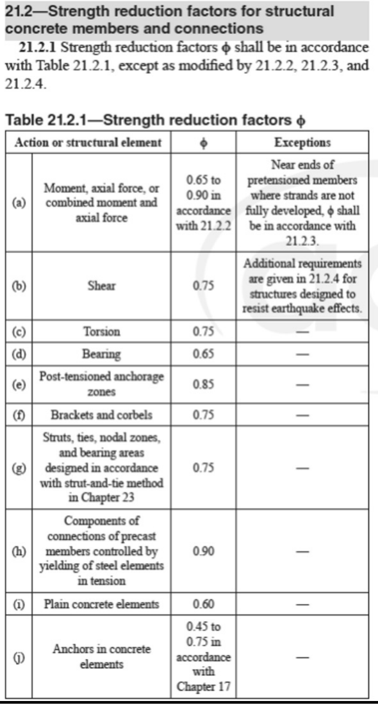
$$f_{cd} = 0{,}85 * \frac{f_{ck}}{2{,}7}$$

$$\therefore f_{cd} \cong 0{,}30\ .\ f_{ck}$$

distribuición del ceficiente $f'_{c,control}/ f'_{c,ext}$



- ✓ **Pilote de fundación: 485 testigos de concreto de 16 obras diferentes;**
- ✓ **Promedio = 1,34 5% superior = 2,12**



21.2—Strength reduction factors for structural concrete members and connections

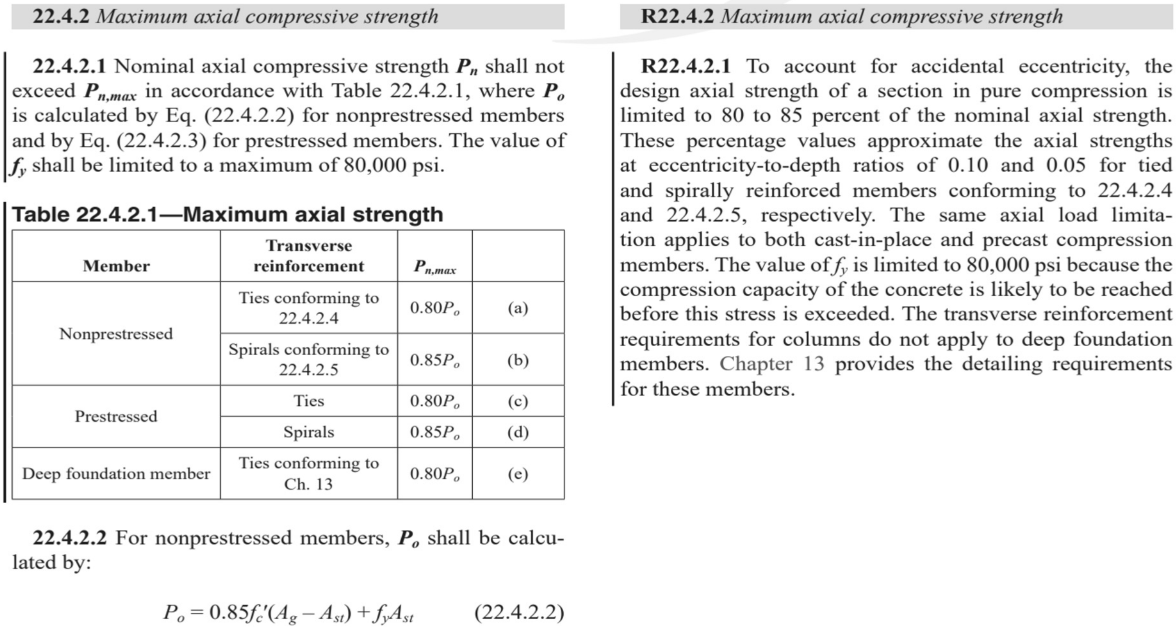
21.2.1 Strength reduction factors ϕ shall be in accordance with Table 21.2.1, except as modified by 21.2.2, 21.2.3, and 21.2.4.

Table 21.2.1—Strength reduction factors ϕ

Action or structural element		ϕ	Exceptions
(a)	Moment, axial force, or combined moment and axial force	0.65 to 0.90 in accordance with 21.2.2	Near ends of pretensioned members where strands are not fully developed, ϕ shall be in accordance with 21.2.3.
(b)	Shear	0.75	Additional requirements are given in 21.2.4 for structures designed to resist earthquake effects.
(c)	Torsion	0.75	—
(d)	Bearing	0.65	—
(e)	Post-tensioned anchorage zones	0.85	—
(f)	Brackets and corbels	0.75	—
(g)	Struts, ties, nodal zones, and bearing areas designed in accordance with strut-and-tie method in Chapter 23	0.75	—
(h)	Components of connections of precast members controlled by yielding of steel elements in tension	0.90	—
(i)	Plain concrete elements	0.60	—
(j)	Anchors in concrete elements	0.45 to 0.75 in accordance with Chapter 17	—

factores de reducción de la resistencia potencial del concreto
ACI 318
(2019/2022)

Máxima resistencia a la compresión para diseño



22.4.2 *Maximum axial compressive strength*

22.4.2.1 Nominal axial compressive strength P_n shall not exceed $P_{n,max}$ in accordance with Table 22.4.2.1, where P_o is calculated by Eq. (22.4.2.2) for nonprestressed members and by Eq. (22.4.2.3) for prestressed members. The value of f_y shall be limited to a maximum of 80,000 psi.

Table 22.4.2.1—Maximum axial strength

Member	Transverse reinforcement	$P_{n,max}$	
Nonprestressed	Ties conforming to 22.4.2.4	$0.80P_o$	(a)
	Spirals conforming to 22.4.2.5	$0.85P_o$	(b)
Prestressed	Ties	$0.80P_o$	(c)
	Spirals	$0.85P_o$	(d)
Deep foundation member	Ties conforming to Ch. 13	$0.80P_o$	(e)

22.4.2.2 For nonprestressed members, P_o shall be calculated by:

$$P_o = 0.85f_c'(A_g - A_{st}) + f_yA_{st} \qquad (22.4.2.2)$$

R22.4.2 *Maximum axial compressive strength*

R22.4.2.1 To account for accidental eccentricity, the design axial strength of a section in pure compression is limited to 80 to 85 percent of the nominal axial strength. These percentage values approximate the axial strengths at eccentricity-to-depth ratios of 0.10 and 0.05 for tied and spirally reinforced members conforming to 22.4.2.4 and 22.4.2.5, respectively. The same axial load limitation applies to both cast-in-place and precast compression members. The value of f_y is limited to 80,000 psi because the compression capacity of the concrete is likely to be reached before this stress is exceeded. The transverse reinforcement requirements for columns do not apply to deep foundation members. Chapter 13 provides the detailing requirements for these members.

29

resistencia de “calculo/diseño” del concreto ACI 318 (2019/2022)

compression-controlled

para f'_c = 30 MPa

$0,65 * 0,85 * 0,80 * 30$

$f'_{c,ef}$ (estructura) ≈ 13 MPa

para f'_c = 50 MPa

0,65 *0,85*0,80* 50

$f'_{c,ef}$ (estructura) ≈ 22 MPa

30

naturaleza del concreto

1. La resistência del concreto **crece** con la edad
2. La resistência del concreto **baja** con la carga mantenida

… ¿cómo **crece** la resistencia del concreto con la edad ?…

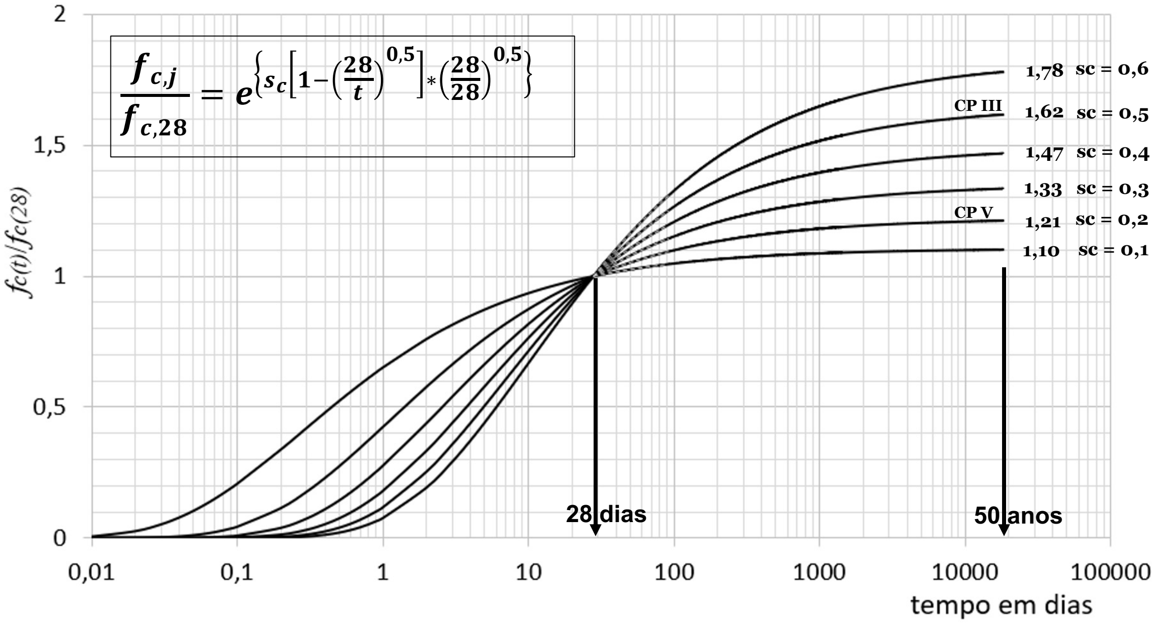
Crecimiento de la Resistencia *fib* Model Code 2020

$$\frac{f_{c,j}}{f_{c,ref}} = e^{\left\{s_c\left[1-\left(\frac{t_{ref}}{t}\right)^{0,5}\right]*\left(\frac{28}{t_{ref}}\right)^{0,5}\right\}}$$

fib Model Code 2020 Item 14.9.1

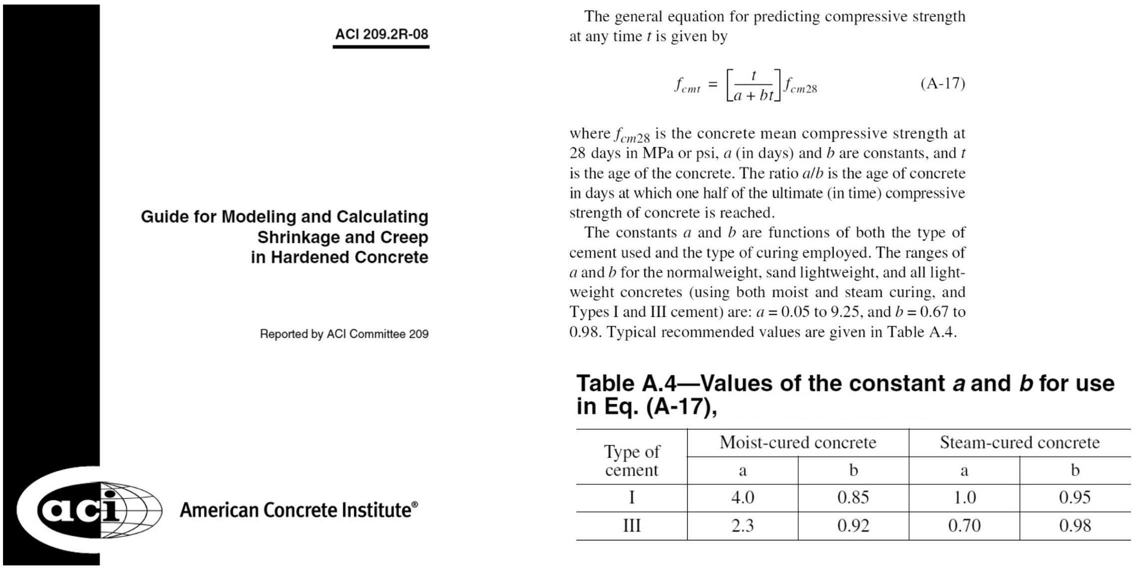
Resistência à compressão do Concreto (MPa)	s_c		
	Classe CS	Classe CN	Classe CR
$f_c \leq 35$	0,6	0,5	0,3
$35 < f_c < 60$	0,5	0,4	0,2
$f_c \geq 60$	0,4	0,3	0,1

Nota: As Classes CS, CN e CR são determinadas em função do tipo e da classe de resistência do cimento. Pode-se admitir, para efeitos de equivalência com os cimentos nacionais: CS (CP III ou CP IV), CN (CP I ou CP II) e CR (CP V). Para determinação das Classes CS, CN e CR, consultar Tabela 14.6.8 "Strength development classes of concrete" do fib Model Code 2020, ou a Table B1 "Strength development classes of concrete" do Eurocode 2:2023 e a norma EN 197-1 "Cement – Part 1: Composition, specifications and conformity criteria for common cements".



$$\frac{f_{c,j}}{f_{c,28}} = e^{\left\{s_c\left[1-\left(\frac{28}{t}\right)^{0,5}\right]*\left(\frac{28}{28}\right)^{0,5}\right\}}$$

Crecimiento de la Resistencia del Concreto
ACI 318 → ACI 209.2R(2008) Appendix A



ACI 209.2R-08

Guide for Modeling and Calculating Shrinkage and Creep in Hardened Concrete

Reported by ACI Committee 209

American Concrete Institute®

The general equation for predicting compressive strength at any time t is given by

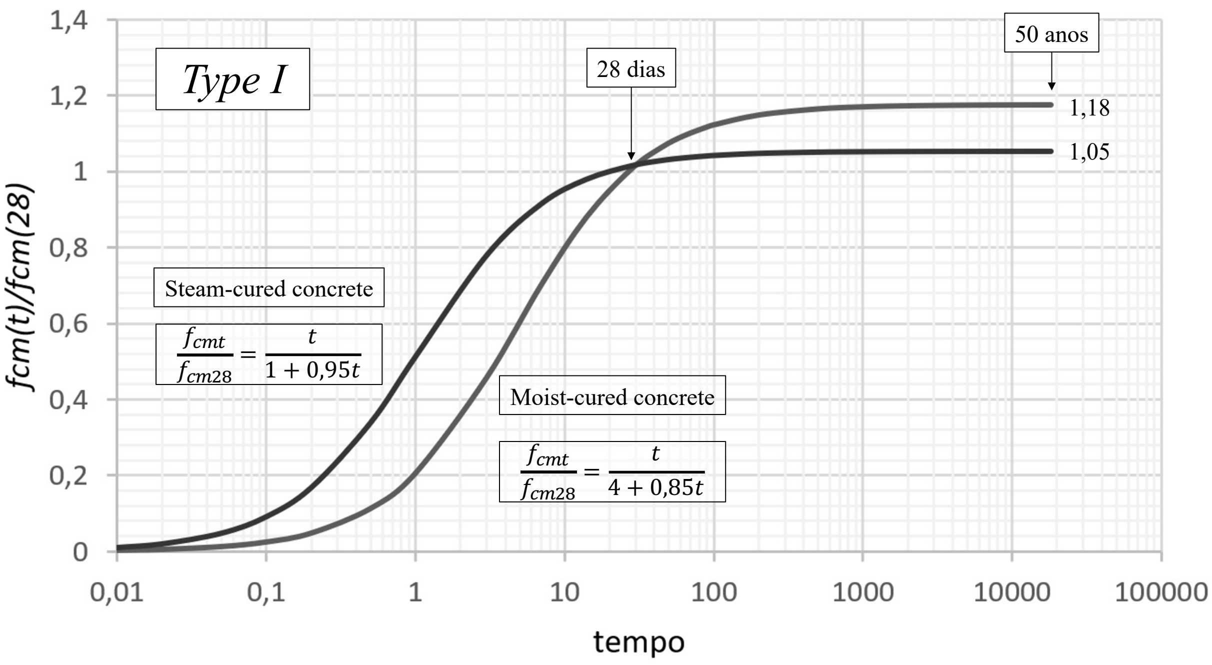
$$f_{cmt} = \left[\frac{t}{a + bt}\right] f_{cm28} \qquad \text{(A-17)}$$

where f_{cm28} is the concrete mean compressive strength at 28 days in MPa or psi, a (in days) and b are constants, and t is the age of the concrete. The ratio a/b is the age of concrete in days at which one half of the ultimate (in time) compressive strength of concrete is reached.

The constants a and b are functions of both the type of cement used and the type of curing employed. The ranges of a and b for the normalweight, sand lightweight, and all lightweight concretes (using both moist and steam curing, and Types I and III cement) are: $a = 0.05$ to 9.25, and $b = 0.67$ to 0.98. Typical recommended values are given in Table A.4.

Table A.4—Values of the constant *a* and *b* for use in Eq. (A-17),

Type of cement	Moist-cured concrete		Steam-cured concrete	
	a	b	a	b
I	4.0	0.85	1.0	0.95
III	2.3	0.92	0.70	0.98



Type I

50 anos

28 dias

Steam-cured concrete

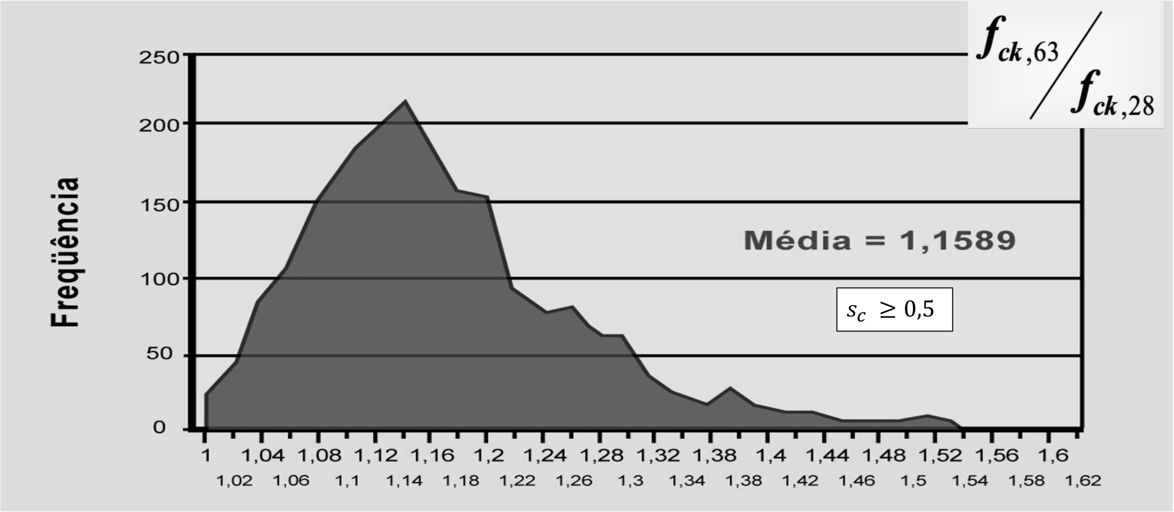
$$\frac{f_{cmt}}{f_{cm28}} = \frac{t}{1 + 0{,}95t}$$

Moist-cured concrete

$$\frac{f_{cmt}}{f_{cm28}} = \frac{t}{4 + 0{,}85t}$$

Análise *(histórica, década 90)*

2.046 Registros Analisados, CP III

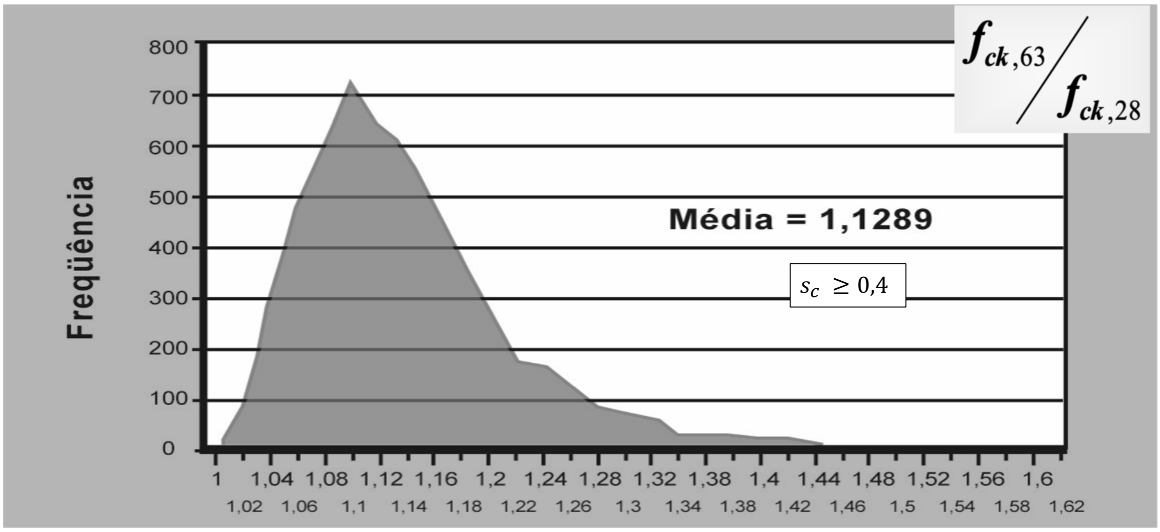


Média = 1,1589

$s_c \geq 0{,}5$

Análise Geral *(histórica, década 90)*

8.429 Registros Analisados, todos os cimentos



Média = 1,1289

$s_c \geq 0{,}4$

Efecto Rüsch

… ¿cómo decrece (baja) la resistencia con la edad ?

Resistencia bajo Carga Mantenida

(efecto Rüsch)

fib Model
Code 2020
Item 14.6.1.6.3

$$\boldsymbol{\beta_{c,sus}\,(t, t_0) = \beta_{t0}(t_0) + [1 - \beta_{t0}(t_0)] * \left[1 + 10^4\,\frac{(t - t_0)}{t_0}\right]^{-0,1}}$$

Sendo:

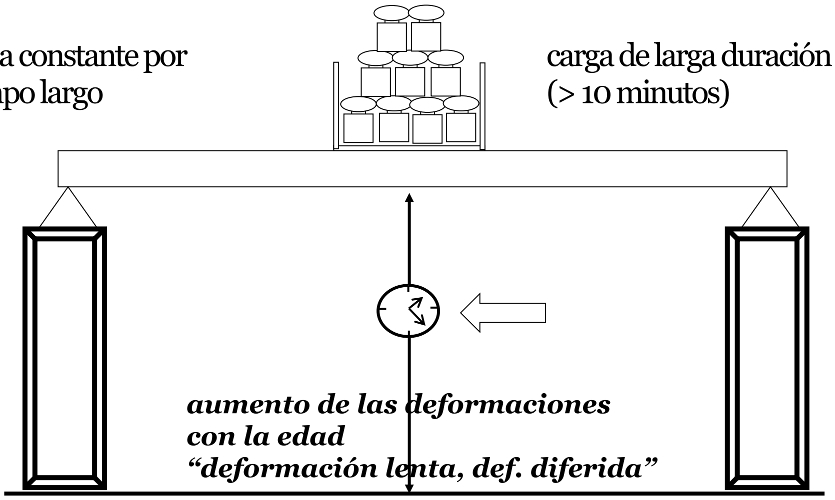
$$\beta_{t0}(t_0) = 0{,}64 + 0{,}01.\,ln(t_0)$$

→ t en dias

→ t_0 → edad de aplicación de las cargas

→ $t - t_o > 15$ minutos

Fluencia

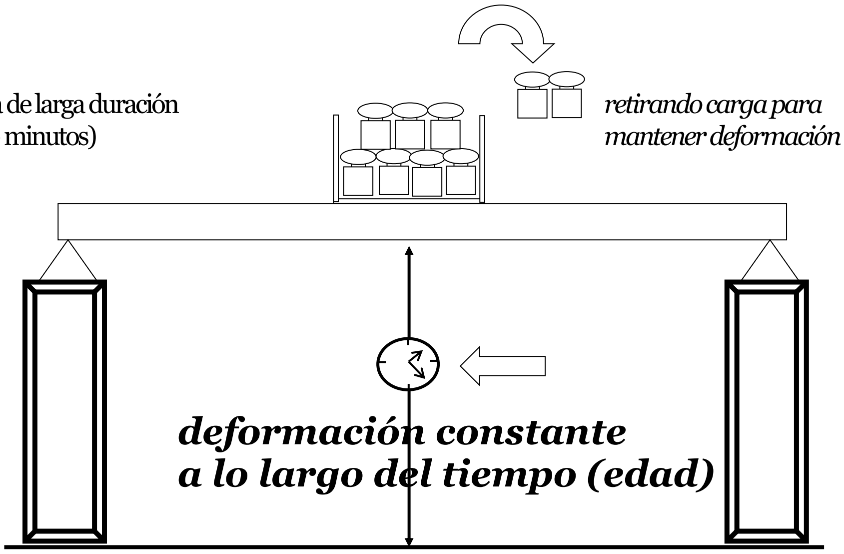


carga constante por
tiempo largo

carga de larga duración
(> 10 minutos)

***aumento de las deformaciones
con la edad
"deformación lenta, def. diferida"***

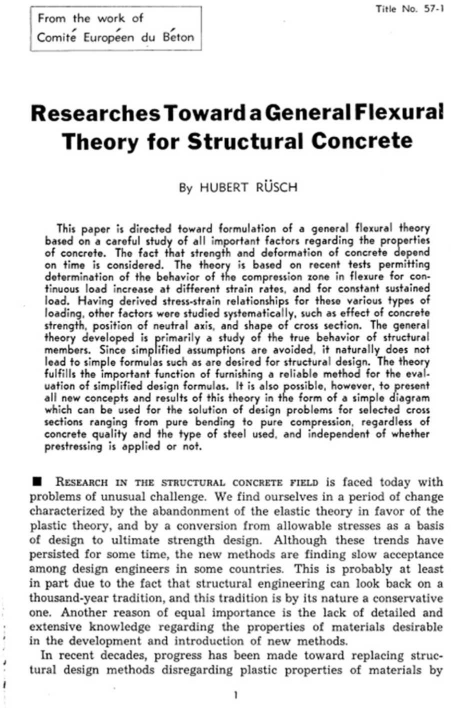
Relajación



carga de larga duración
(> 10 minutos)

*retirando carga para
mantener deformación cte.*

***deformación constante
a lo largo del tiempo (edad)***



From the work of
Comité Européen du Béton

Title No. 57-1

Researches Toward a General Flexural Theory for Structural Concrete

By HUBERT RÜSCH

This paper is directed toward formulation of a general flexural theory based on a careful study of all important factors regarding the properties of concrete. The fact that strength and deformation of concrete depend on time is considered. The theory is based on recent tests permitting determination of the behavior of the compression zone in flexure for continuous load increase at different strain rates, and for constant sustained load. Having derived stress-strain relationships for these various types of loading, other factors were studied systematically, such as effect of concrete strength, position of neutral axis, and shape of cross section. The general theory developed is primarily a study of the true behavior of structural members. Since simplified assumptions are avoided, it naturally does not lead to simple formulas such as are desired for structural design. The theory fulfills the important function of furnishing a reliable method for the evaluation of simplified design formulas. It is also possible, however, to present all new concepts and results of this theory in the form of a simple diagram which can be used for the solution of design problems for selected cross sections ranging from pure bending to pure compression, regardless of concrete quality and the type of steel used, and independent of whether prestressing is applied or not.

■ RESEARCH IN THE STRUCTURAL CONCRETE FIELD is faced today with problems of unusual challenge. We find ourselves in a period of change characterized by the abandonment of the elastic theory in favor of the plastic theory, and by a conversion from allowable stresses as a basis of design to ultimate strength design. Although these trends have persisted for some time, the new methods are finding slow acceptance among design engineers in some countries. This is probably at least in part due to the fact that structural engineering can look back on a thousand-year tradition, and this tradition is by its nature a conservative one. Another reason of equal importance is the lack of detailed and extensive knowledge regarding the properties of materials desirable in the development and introduction of new methods.

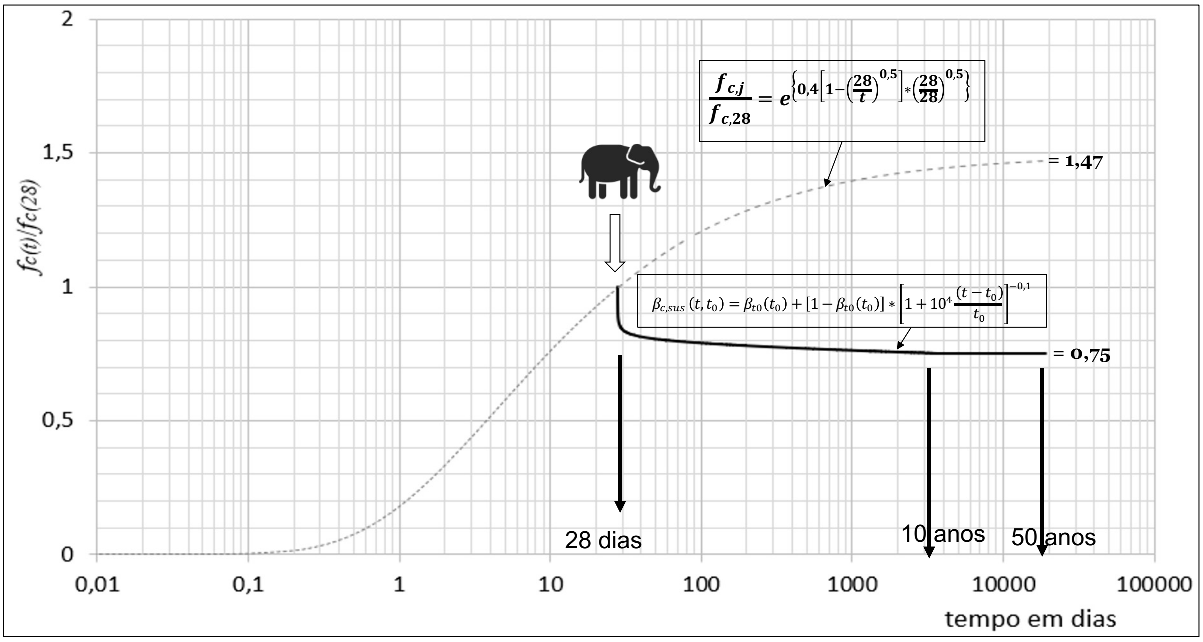
In recent decades, progress has been made toward replacing structural design methods disregarding plastic properties of materials by

1

RÜSCH, Hubert. **Researches Toward a General Flexural Theory for Structural Concrete**. ACI Journal: Proceedings. [s.l.] Julho, 1960. 28p.

(download y consulta free en la biblioteca de la PhD- www.phd.eng.br)

Decréscimo de la Resistencia

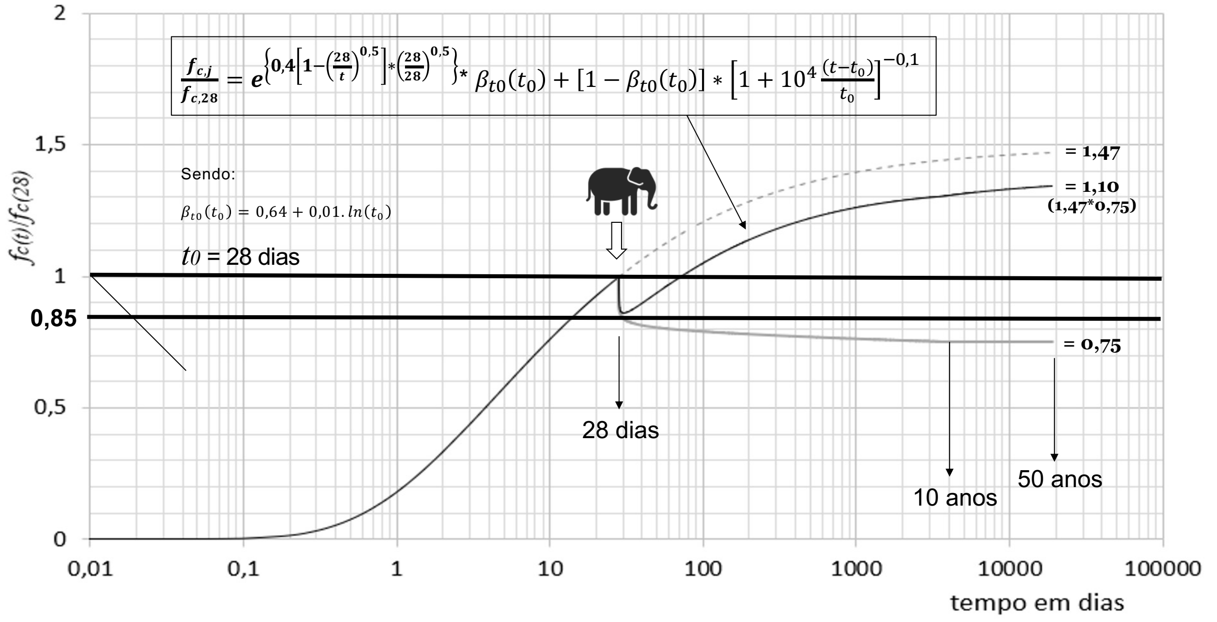


$$\frac{f_{c,j}}{f_{c,28}} = e^{\left\{0,4\left[1-\left(\frac{28}{t}\right)^{0,5}\right]*\left(\frac{28}{28}\right)^{0,5}\right\}}$$

$$\beta_{c,sus}(t,t_0) = \beta_{t0}(t_0) + [1-\beta_{t0}(t_0)] * \left[1 + 10^4\frac{(t-t_0)}{t_0}\right]^{-0,1}$$

...combinando crecimiento con decrecimiento a partir de 28dias ...

Resistencia del Concreto “cargado” a lo largo de la edad



$$\frac{f_{c,j}}{f_{c,28}} = e^{\left\{0,4\left[1-\left(\frac{28}{t}\right)^{0,5}\right]*\left(\frac{28}{28}\right)^{0,5}\right\}} * \beta_{t0}(t_0) + [1-\beta_{t0}(t_0)] * \left[1+10^4\,\frac{(t-t_0)}{t_0}\right]^{-0,1}$$

Sendo:

$\beta_{t0}(t_0) = 0,64 + 0,01.\,ln(t_0)$

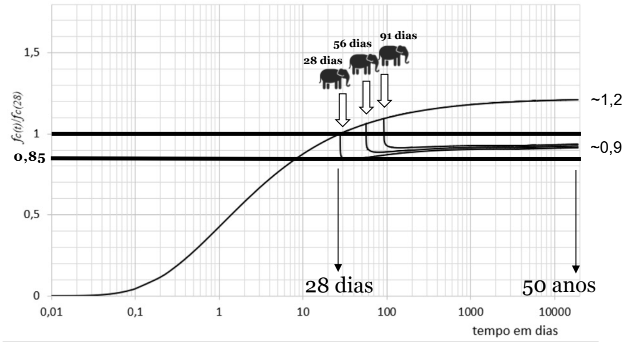
t_0 = 28 dias

Cálculo del f_{cd} según vários codes

$f_{ck28} = f'_{c28}$ = 20 a 40 MPa con (s=0,2)

t_{ref} = 28 dias

t_{carga} = 28 dias **t_{carga} = 56 dias** **t_{carga} = 91 dias**



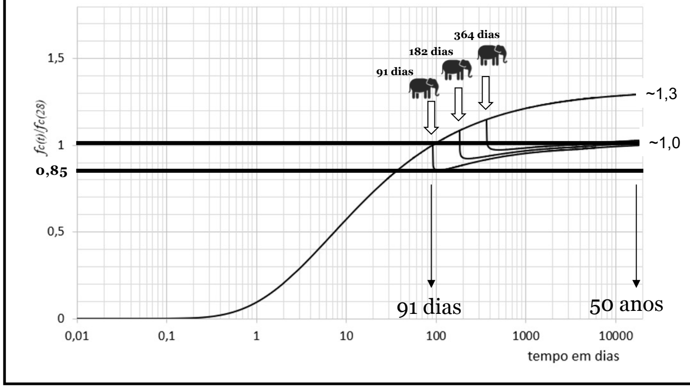
ACI 318 2019/2022	ABNT NBR 6118:2023	*fib* Model Code 2020 (MC 2020)	Eurocode 2: 2023
0,44 a 0,60*f'_c	0,61*f_{ck}	0,67*f_{ck}	0,67*f_{ck}
0,44 a 0,60*f'_c	0,61*f_{ck}	0,67*f_{ck}	0,67*f_{ck}
0,44 a 0,60*f'_c	0,61*f_{ck}	0,67*f_{ck}	0,67*f_{ck}

Cálculo del f_{cd} según vários codes

$f_{ck91} = f'_{c91}$ = 20 a 40 MPa con (s=0,3)

t_{ref} = 91 dias

t_{carga} = 91 dias **t_{carga} = 182 dias** **t_{carga} = 364 dias**

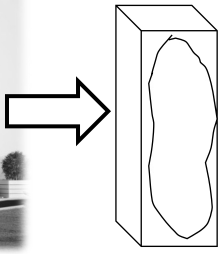


ACI 318 2019/2022	ABNT NBR 6118:2023	*fib* Model Code 2020 (MC 2020)	Eurocode 2: 2023
0,44 a 0,60*f'_c	*nihil*	0,57*f_{ck}	0,57*f_{ck}
0,44 a 0,60*f'_c	*nihil*	0,57*f_{ck}	0,57*f_{ck}
0,44 a 0,60*f'_c	*nihil*	0,57*f_{ck}	0,57*f_{ck}

Introdución de la sostenibilidad en el diseño estructural

Edifício residencial de estructura de concreto armado con 24 pisos tipo + 2 subsuelos.

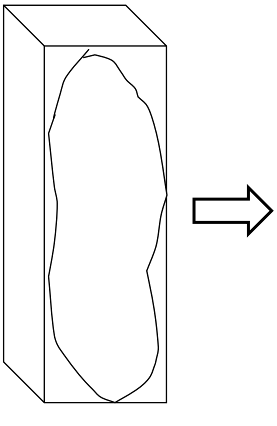
Área del piso tipo: 365 m²



Análisis de un tramo pilar/columna corto de sección quadrada, localizado entre el 1° e 2° piso (altura 2,88 m).

Edifício con 1008 tramos de pilar

Premisas para el dimensionamiento del pilar/columna



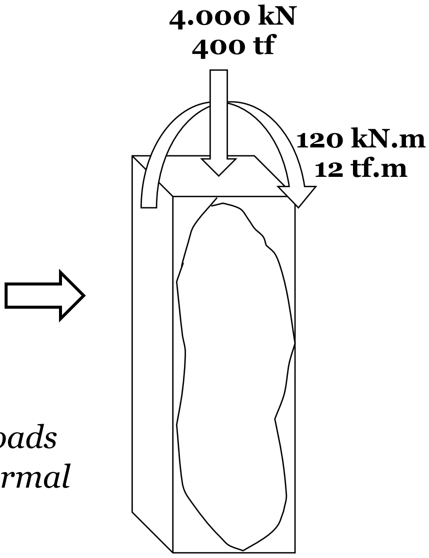
Fuerza normal nominal:

Nsk = 4000 KN = 400 tf

Momentos totales nominales:

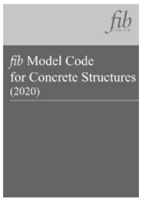
Mxsk = 120 kN.m = 12 tf.m
Mysk = 120 kN.m = 12 tf.m

Considera-se que las acciones live loads corresponden a 25% de la fuerza normal total



Normativas utilizadas

- ✓ *ABNT NBR 6118:2023*
- ✓ *fib Model Code 2020*



fib

fib Model Code
for Concrete Structures
(2020)

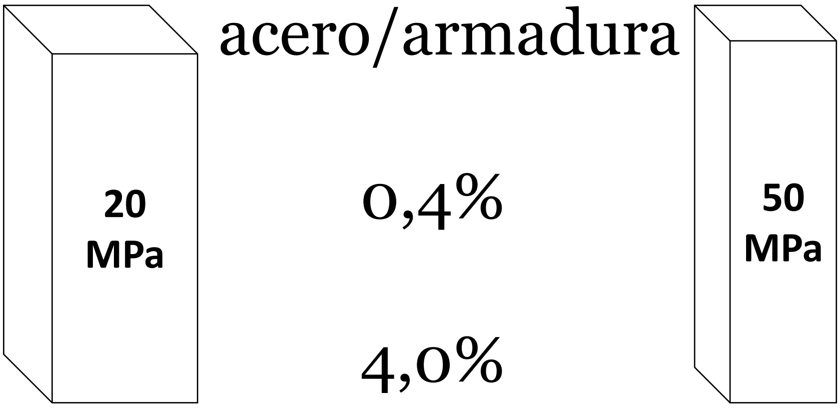
- ✓ *Eurocode 2:2023*

Eurocode 2 — Design of concrete structures —

Part 3: Liquid retaining and containment structures

Dimensionamiento del pilar corto

- ✓ *2 cuantías de acero/armadura: una mínima (≥ 0,4%) e una máxima para emendas por traspasse (< 4,0%);*
- ✓ *2 diferentes clases de resistencia del concreto, C20 e C50, con f_{ck} referido a 3 diferentes edades: 28, 56 y 91 dias.*
- ✓ *concretos mezclados con dos diferentes clases de cemento; CR (alta resistência inicial) e CS (lentos, con adiciones).*



acero/armadura

0,4%

4,0%

cemento; agregados; aditivos; mezcla; fecha del f'_c

dosificación del concreto

f'_c = 20 MPa

→ 28 días

- $f_{cm} = f'c + 8$ = 28 MPa
- cemento CR → 9 kg/MPa
- contenido = 28*9 = 252 kg/m^3

- cemento CS → 10 kg/MPa
- contenido = 28*10 = 280 kg/m^3

f'_c = 50 MPa

→ 56 días

- $f_{cm} = f'c + 8$ = 58 MPa

→ 28 días → 56/1,12 = 50 MPa

- cemento CR → 7,0 kg/MPa
- contenido = 50*7,0 = 350 kg/m^3

- cemento CS → 7,5 kg/MPa
- contenido = 50*7,5 = 375 kg/m^3

para los cálculos de las emisiones de CO_2 fueran utilizados datos disponíbles en:

*Cimento CP III Santa Helena -Votorantim **384 kg CO_2 eq.** por tonelada.*
*Cimento CP V Santa Helena -Votorantim **852 kg CO_2 eq.** por tonelada.*

***8 kg CO_2 eq.** por metro quadrado de fôrma.*

*Aço CA 50 ArcelorMittal Piracicaba **786 kg CO_2 eq.** por tonelada.*

Los datos utilizados ficaram dentro de los intervalos de SIDAC.

440 *kgCO_2eq.*

180 *kgCO_2eq.*

50 cm

45 cm

***f'$_{ck}$* 28 dias**

CR

4,0%

20 MPa

50 MPa

***f$_{ck}$* 56 dias**

CS

1,0%

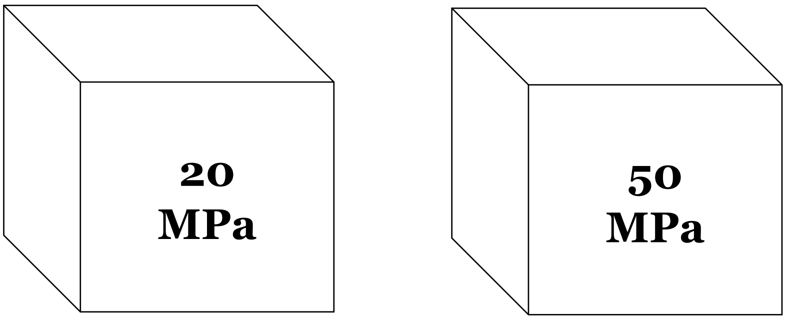
0,72 m^3

-24%

0,58 m^3

440 $kgCO_2eq.$

200 $kgCO_2eq.$



50 cm

f_{ck} 28 dias

CR

4,0%

20 MPa

50 cm

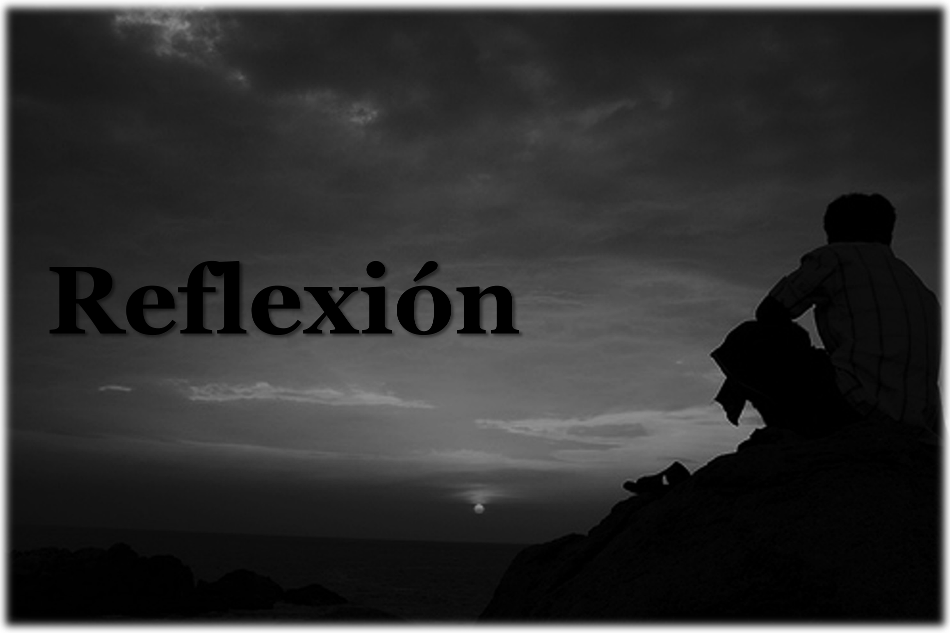
f_{ck} 56 dias

CS

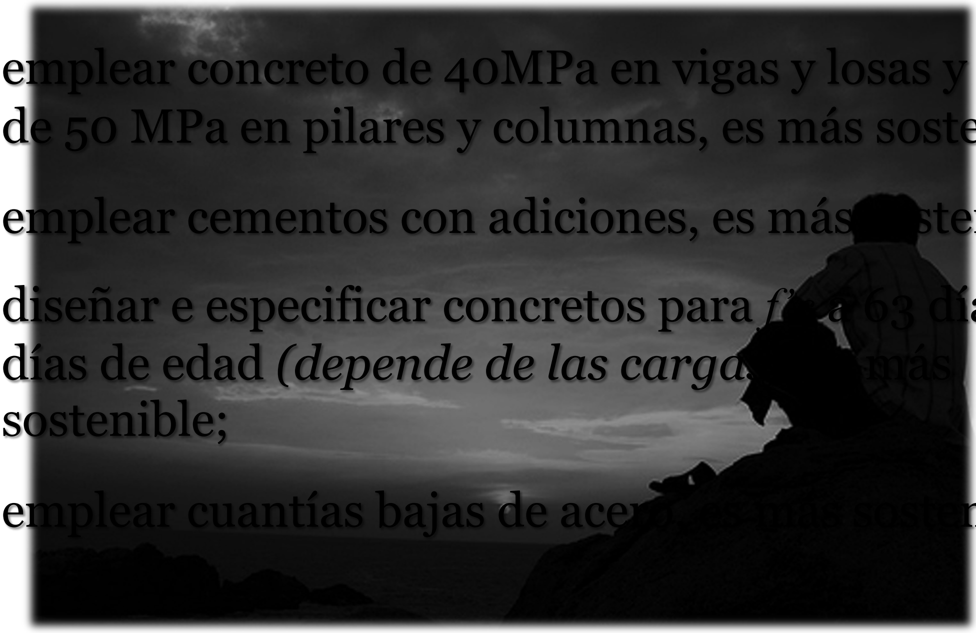
0,8%

50 MPa

1008 tramos → 242 toneladas



Reflexión



1. emplear concreto de 40MPa en vigas y losas y acima de 50 MPa en pilares y columnas, es más sostenible;
2. emplear cementos con adiciones, es más sostenible;
3. diseñar e especificar concretos para f'_c a 63 días e 91 días de edad *(depende de las cargas)*, es más sostenible;
4. emplear cuantías bajas de acero, es más sostenible;

sabendo que:

resistencia crece así →

$$\boldsymbol{\beta_{cc}} = \frac{\boldsymbol{f_{c,j}}}{\boldsymbol{f_{c,28}}} = \boldsymbol{e}^{\left\{ s_c \left[1 - \left(\frac{t_{ref}}{t} \right)^{0,5} \right] * \left(\frac{28}{t_{ref}} \right)^{0,5} \right\}}$$

resistencia decrece así →

$$\boldsymbol{\beta_{c,sus}(t, t_0) = \beta_{t0}(t_0) + [1 - \beta_{t0}(t_0)] * \left[1 + 10^4 \frac{(t - t_0)}{t_0} \right]^{-0,1}}$$

Porque usar coeficientes o factores empíricos?

α_{cc}= 0 [illegible] **1,00**

$f_{cd} = \alpha$ [illegible] $* \eta_{fc} * \frac{f_{ck}}{\gamma_c}$

$\eta_{fc} = \Big($ [illegible] $\leq 1,0\ MPa$

(0,65 a 0,90) * [illegible] 0 a 0,85) * 0,80 * $\boldsymbol{f'_c}$

quizá usar →

$$f_{cd} = \boldsymbol{\beta_{cc}} * \boldsymbol{\beta_{c,sus}} * \frac{f_{ck}}{\gamma_c}$$

GRACIAS POR SU ATENCIÓN

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