fib

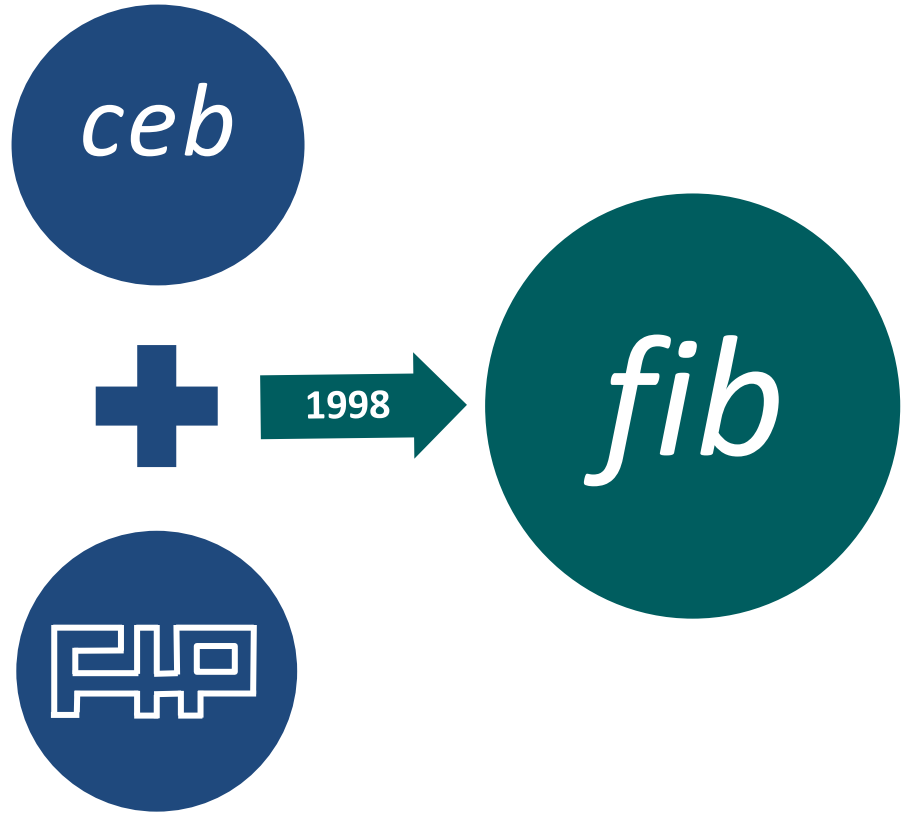
Concrete International Federation

Hugo Corres

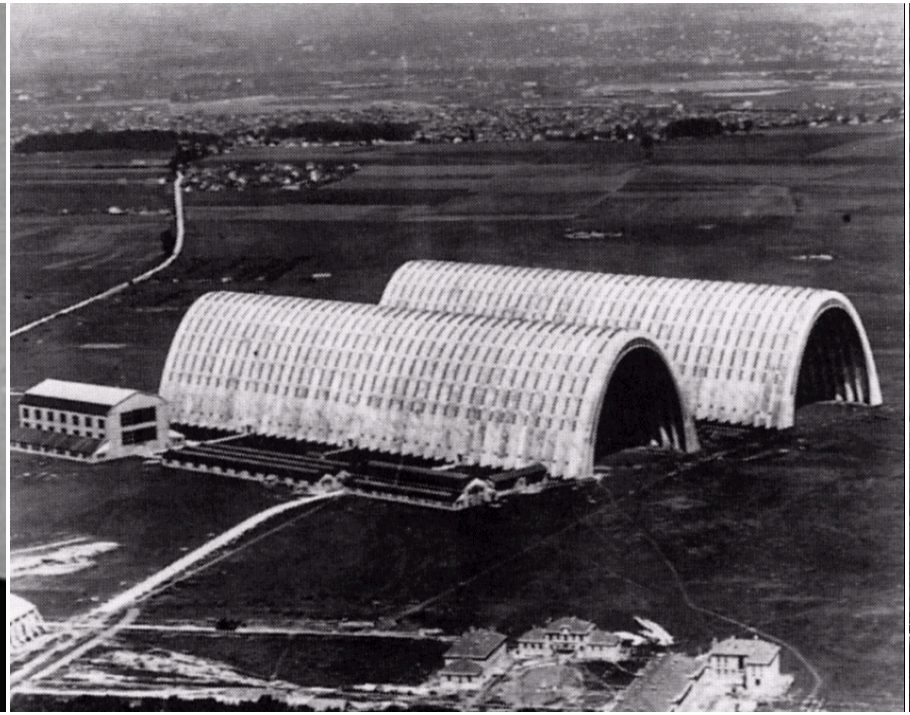
Presidente da fib

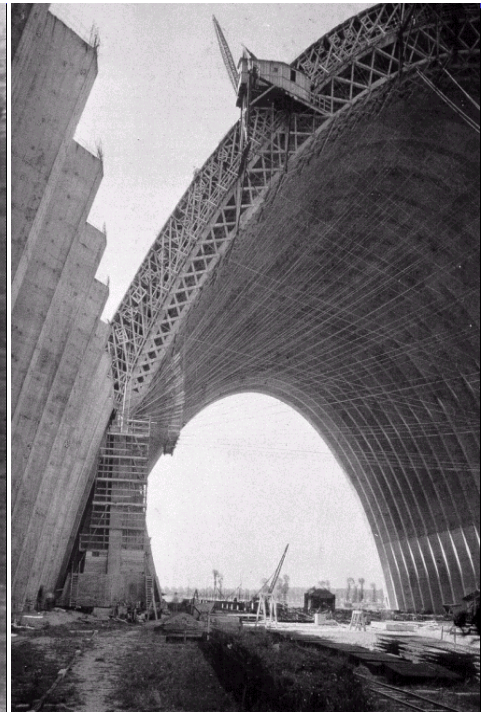
Euro-International
Committee for Concrete
Comité euro-internationale du béton
1953

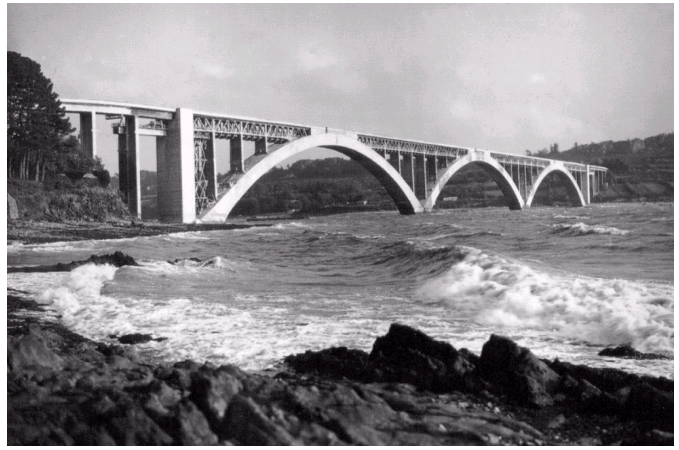
International Federation
of Pre-stressing
Fédération internationale
de la précontrainte
1952

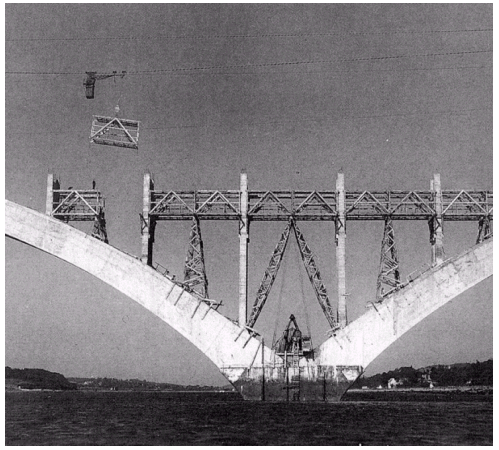


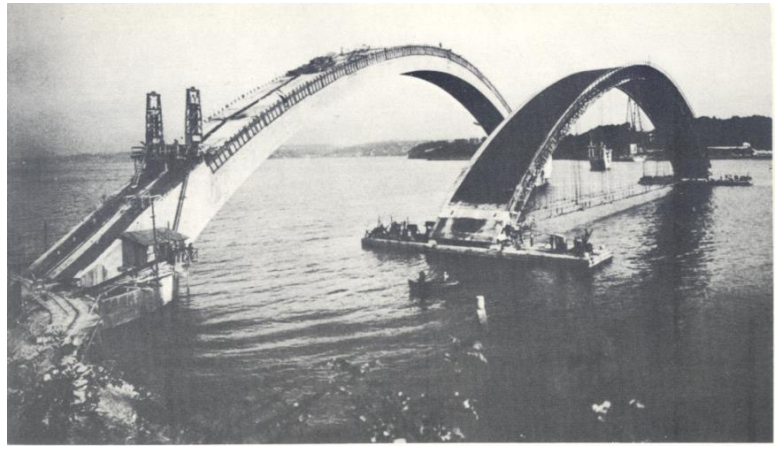
EUGÈNE FREYSSINET (1879-1962)



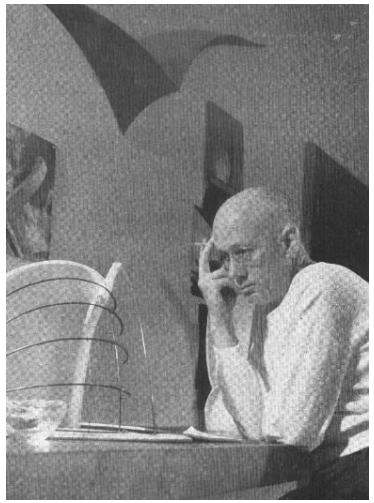


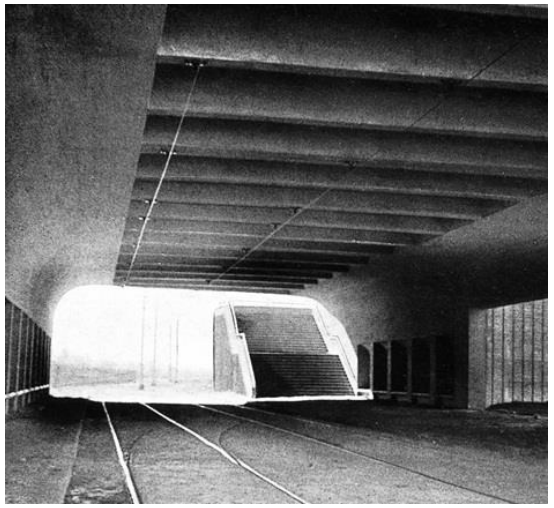


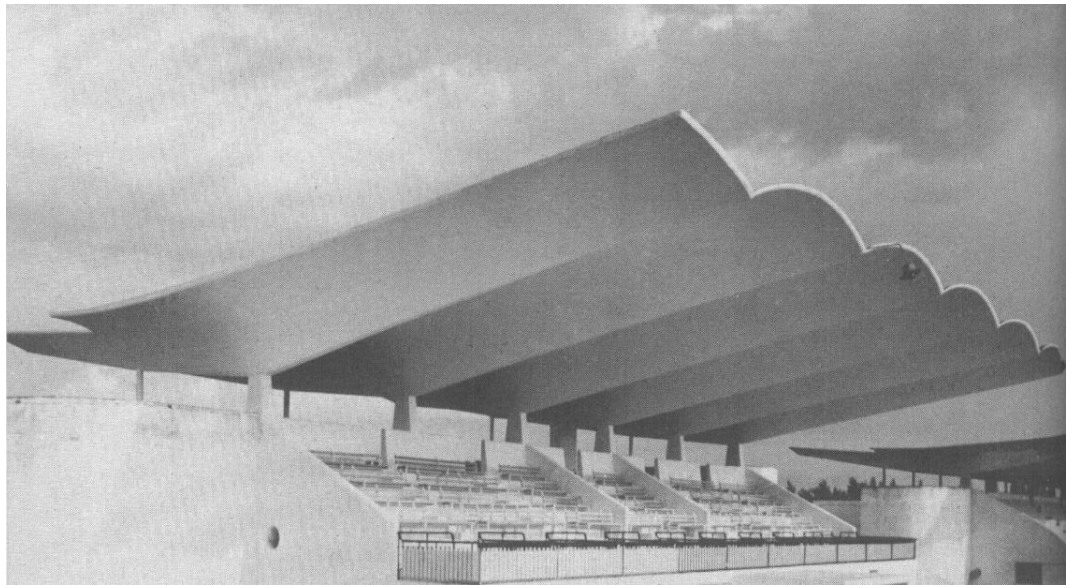


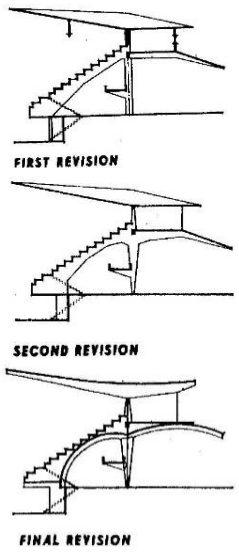


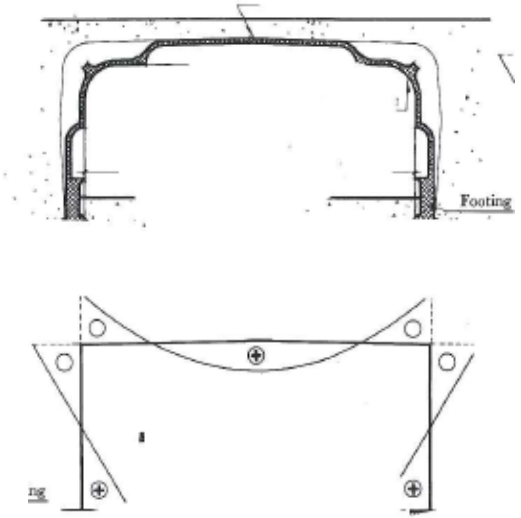
EDUARDO TORROJA (1899-1961)







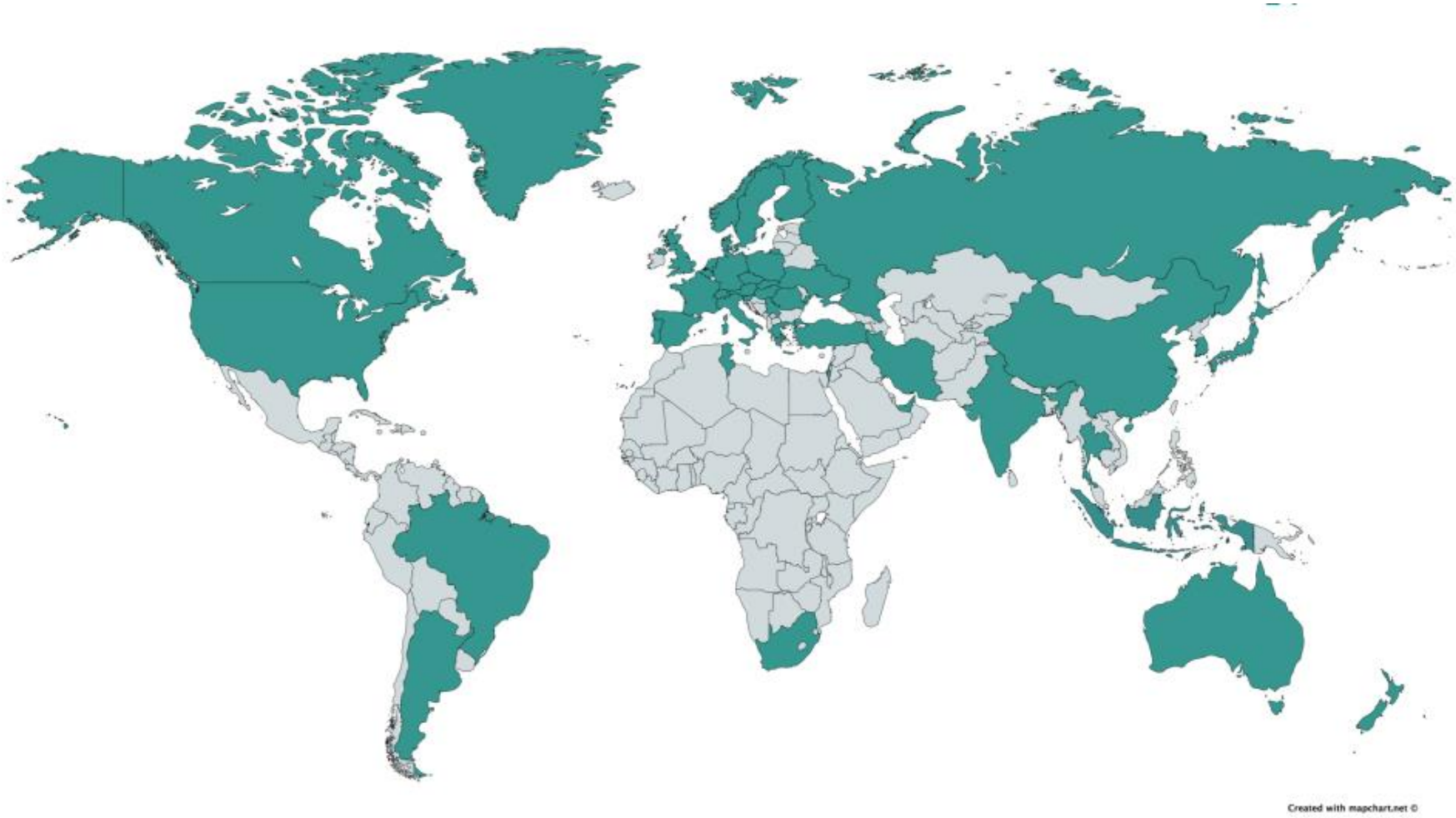




MISSION AND OBJECTIVES OF THE *fib*

"To develop at an international level the study of scientific and practical matters capable of advancing the technical, economic, aesthetic and environmental performance of concrete construction." ***Statutes of the fib***

fib 2018 STATUTORY MEMBER COUNTRIES

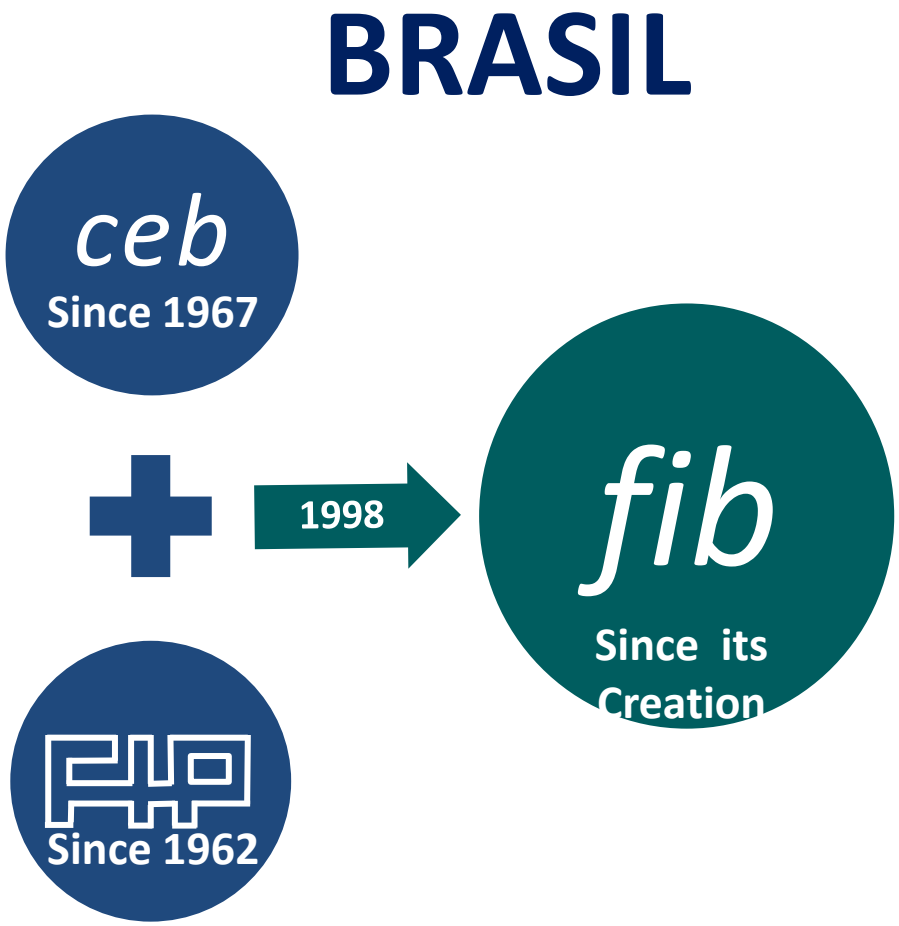


Argentina – Australia – Austria – Belgium – Brazil – Canada – China – Cyprus – Czech Republic– Denmark – Finland – France – Germany – Greece – Hungary – India – Indonesia – Iran – Israel – Italy – Japan – Lebanon – Luxembourg – Netherlands – New Zealand – Norway – Poland – Portugal – Romania – Russia – Serbia – Slovakia – Slovenia – South Africa – South Korea – Spain – Sweden – Switzerland – Thailand – Tunisia – Turkey – UAE – Ukraine – United Kingdom – United States

CREATION OF *fib*

Euro-International
Committee for Concrete
Comité euro-internationale du béton
1953

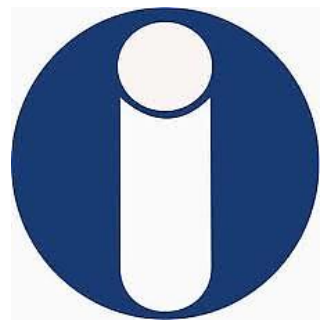
International Federation
of Pre-stressing
Fédération internationale
de la précontrainte
1952



fib
CEB-FIP
BRAZIL

Abcic
Associação Brasileira da Construção
Industrializada de Concreto

ASSOCIAÇÃO
BRASILEIRA DE
ENGENHARIA E
CONSULTORIA
ESTRUTURAL
ABECE



Brazil fib delegation

Delegate and Head of the Delegation Fernando Stucchi (ABECE)

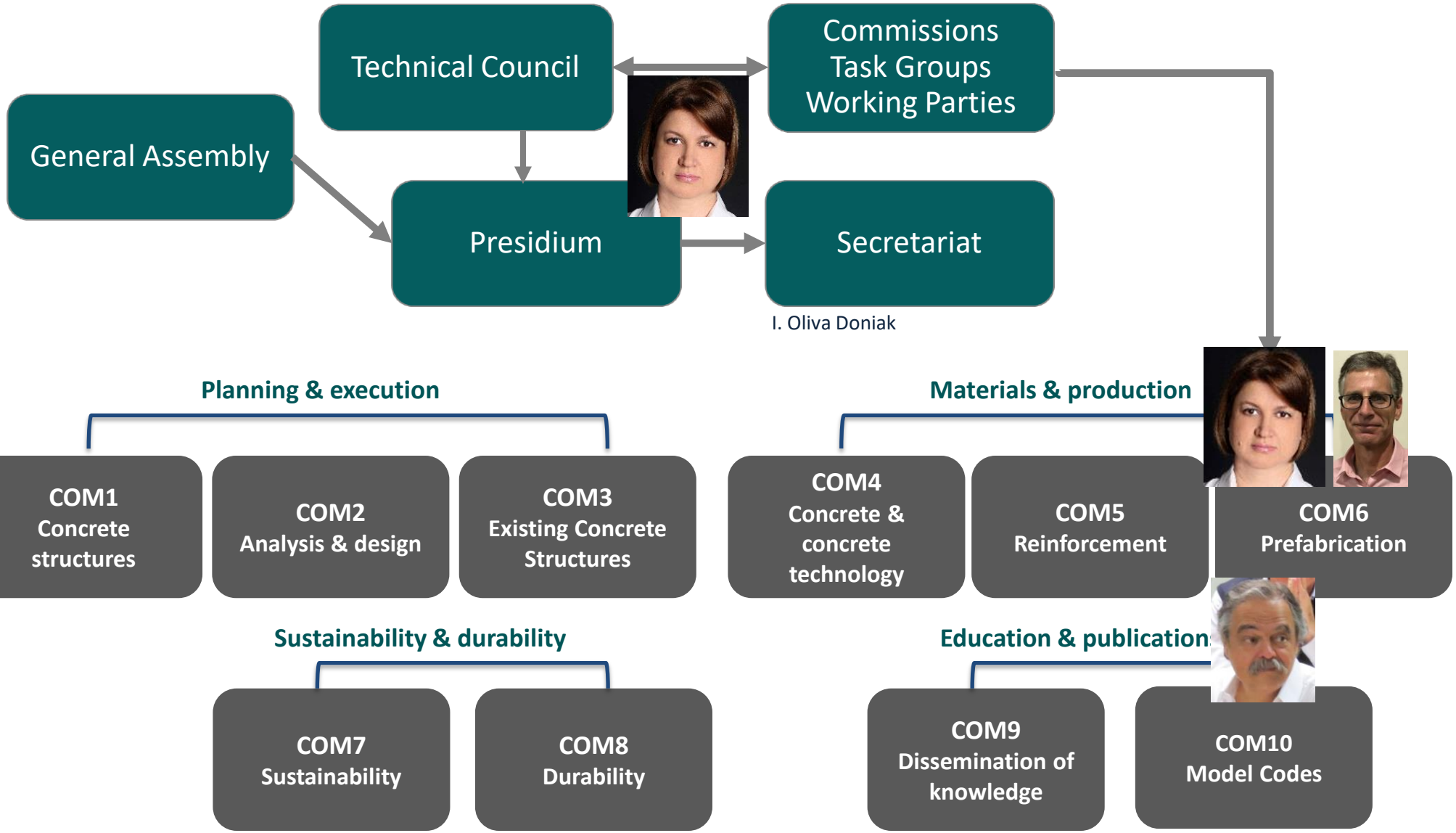
Deputy Lidia Sheata (ABECE)

Delegate Íria Doniak (ABCIC)

Deputy – Julio Timermann (IBRACON)

DEHN
Germany
BALÁZS
Hungary
STUCCHI
Brazil
DONIAK
Brazil
TOSCAS
USA
22
23
24
42
45

THE *fib's* STRUCTURE



- Between the late 80’s and early 90’s Augusto Carlos de Vasconcelos and Lidia Shehata were part of ceb-FIP.

- COLLOQUIUM ON THE CEB-FIP MC90 in Rio de Janeiro in 1991.

- After a difficult period, in 2008 Brazil recovers its participation in fib with the support of ABCIC and ABECE.

- With the organization of the Workshop on fib MC2020 in Sao Paulo – 2018 it was possible to recover the participation of IBRACON in our National Member Group.

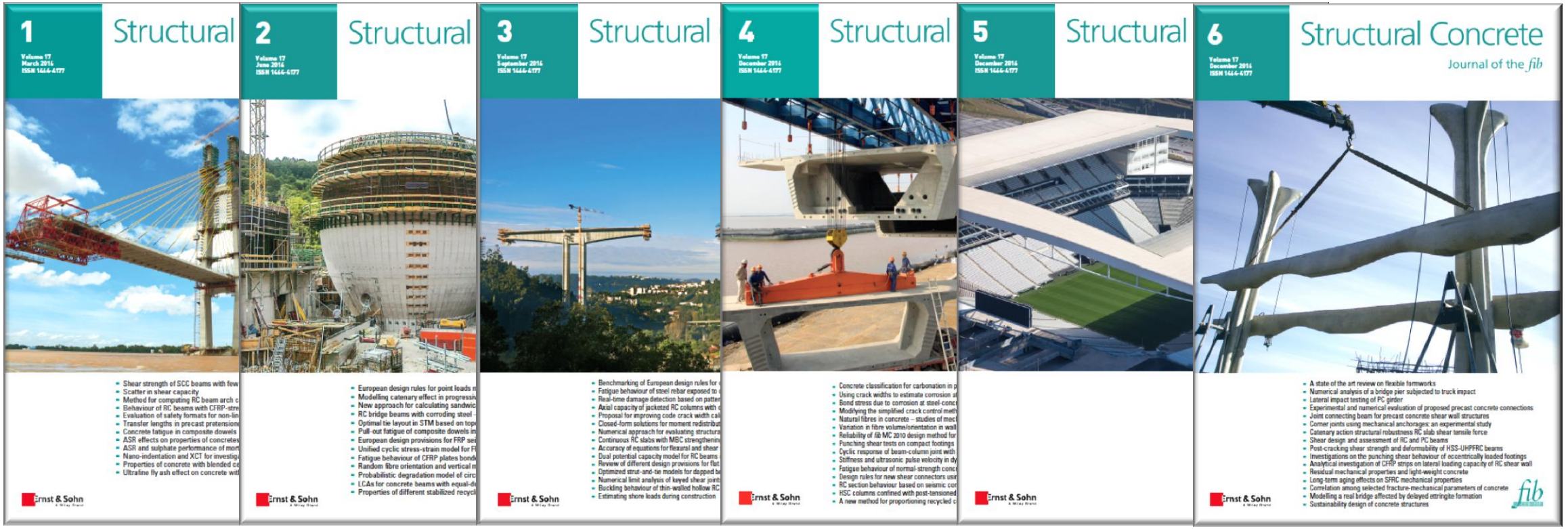
- 2008 ABCIC started participating in fib Com 6
- 2012 ABCIC hosted Com 6 meeting in Sao Paulo
- 2012 fib ABCIC Latin America Seminar on Precast Concrete Structures. Sao Paulo
- 2012 ABCIC ANIPB and fib Com 6 presentation Estruturas Pré-Fabricadas no Mundo- Aplicações e Comportamento Estrutural. São Paulo
- 2014 fib ABECE presentation MC 2010 in Sao Paulo

- 2016 fib ABCIC presentation of Bulletin 74 Planning and Design handbook on precast Concrete Structures in Sao Paulo
- 2016 fib ABECE Short Course on Strut-and-Tie by Aurelio Muttoni in Sao Paulo
- 2016 Com5 Meeting in Brasilia

SAÍDA

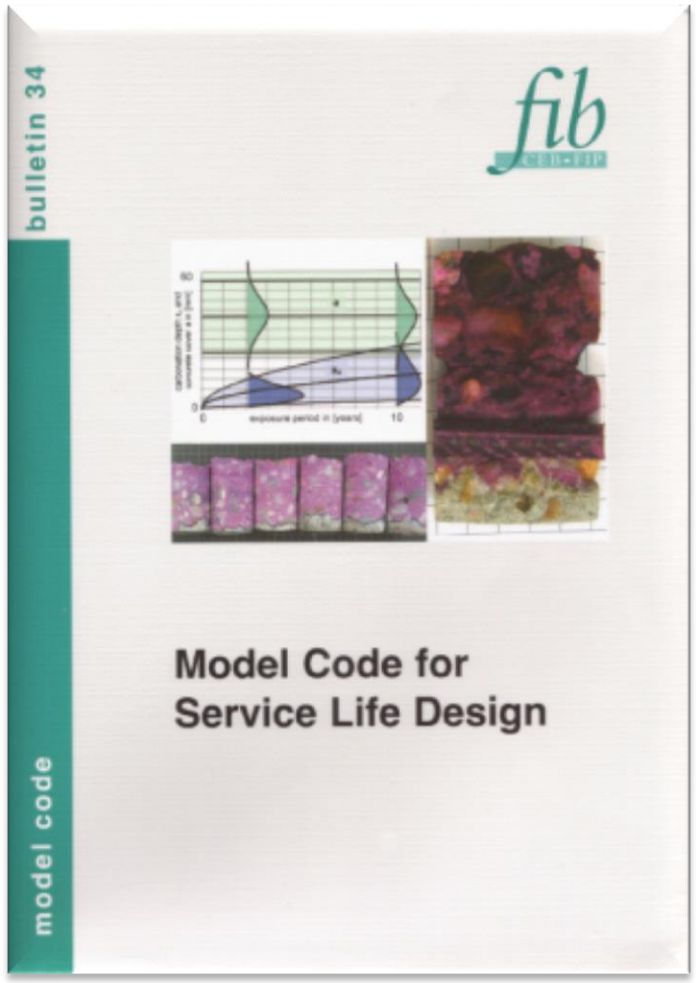
The *fib's* Structural Concrete Journal

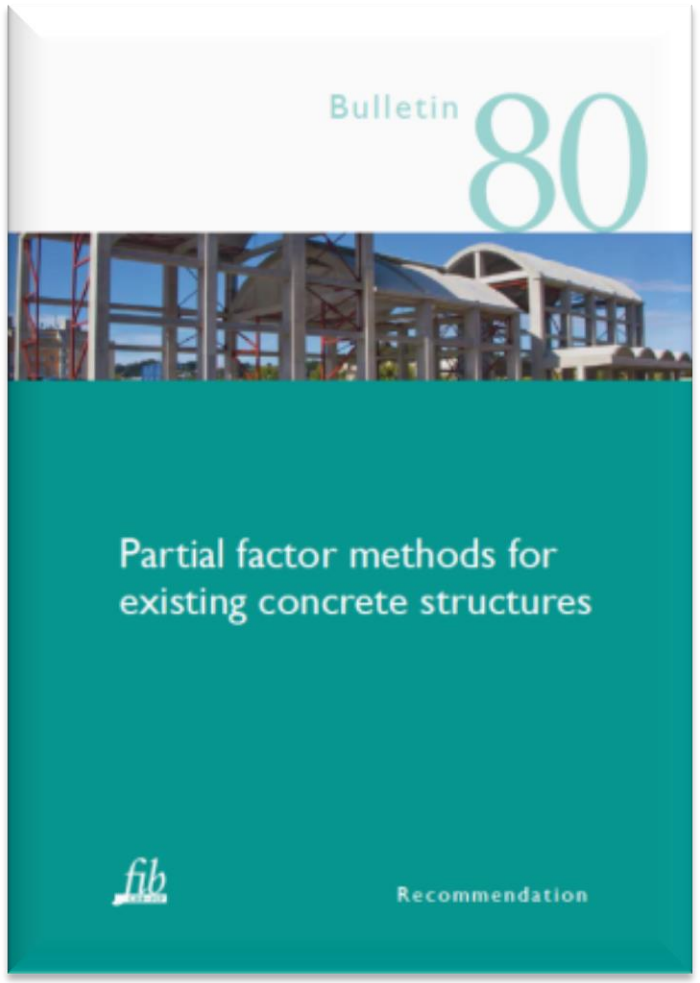
Impact factor 2017: 1.424
6 issues from 2016



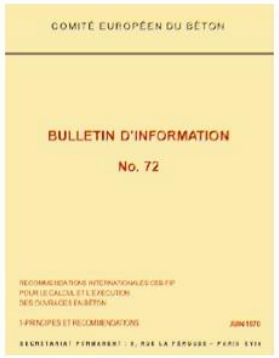
RESULTS OF COMMISSIONS AND TASK GROUPS ARE PUBLISHED AS *fib* BULLETINS

- Technical reports
- State-of-the-art reports
- Textbooks
- Manuals or guides
- Recommendations
- Model Codes

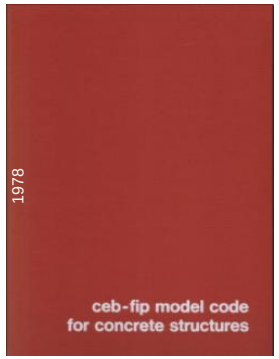




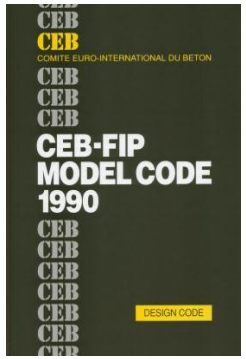
fib (CEB/FIP) MODEL CODES



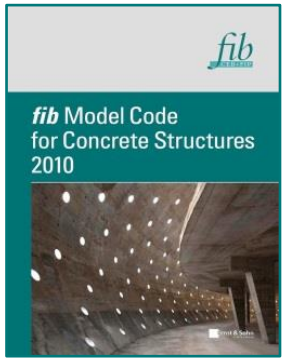
Model Code 1970



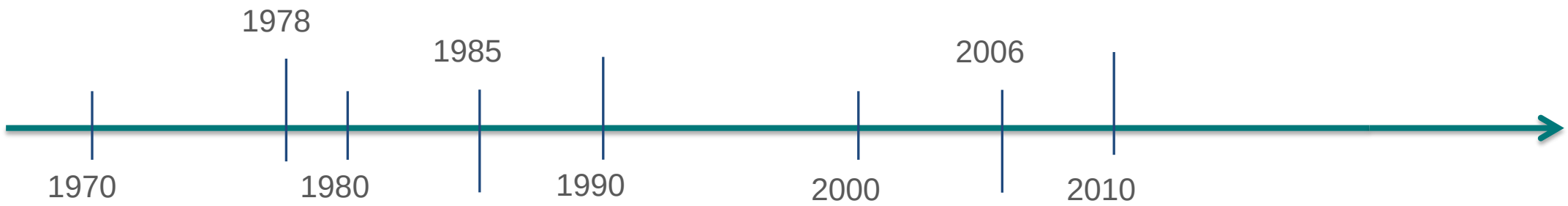
Model Code

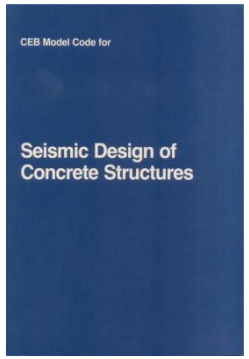


Model Code

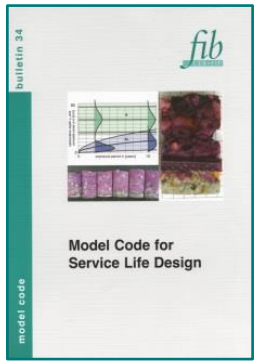


Model Code





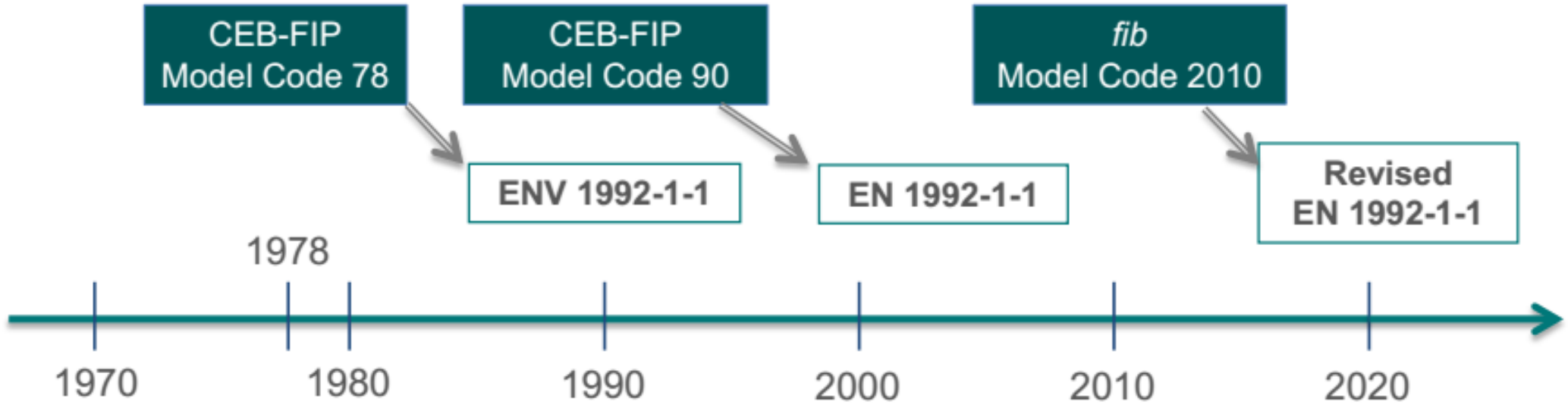
CEB Bull. 165 Seismic Design



fib Bull. 34 Service Life Design

IMPACT OF *fib* (CEB/FIP) MODEL CODES

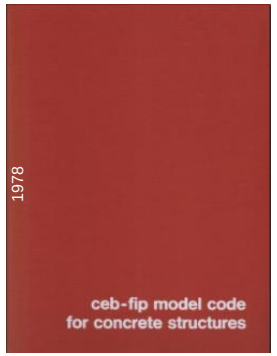
Strong influence on CEN Eurocodes (36 countries, 600 million people)



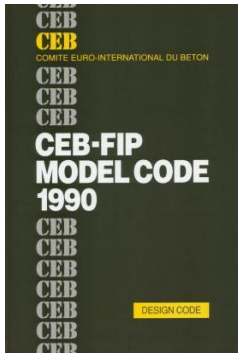
Pronounced influence on Asian and African Model Codes

Model Codes are used as reference documents both in research and in design

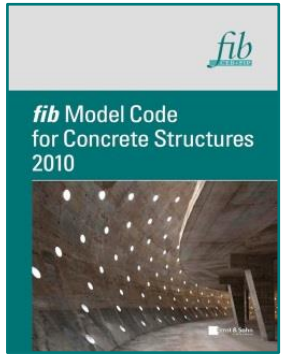
fib EVOLUTION OF MODEL CODES



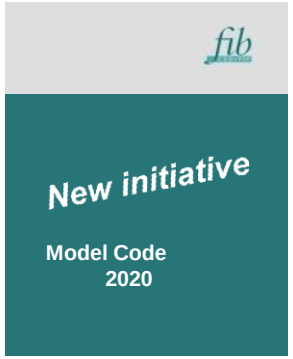
Model Code 1978



Model Code 1990



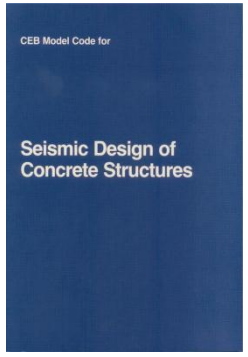
Model Code 2010



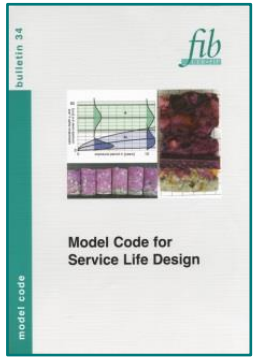
Model Code 2020

1970 1980 1990 2000 2010 2020

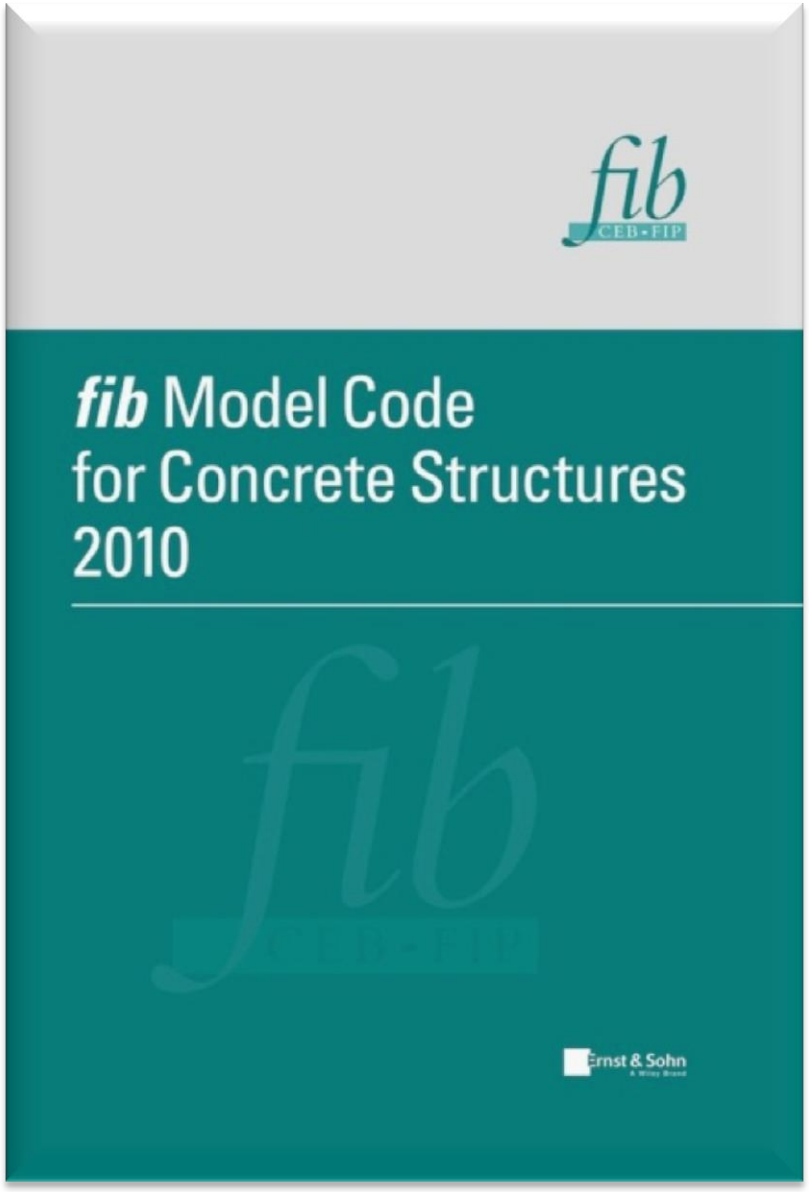
1978 1985 2006



CEB Bull. 165 Seismic Design



fib Bull. 34 Service Life Design



Preface

Notations

PART I: PRINCIPLES

PART II: DESIGN INPUT DATA

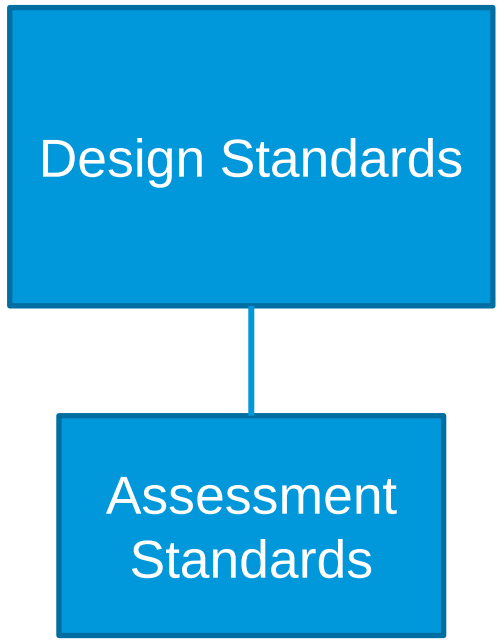
PART III: DESIGN

PART VI: CONSTRUCTION

PART V: CONSERVATION AND DISMANTLEMENT

- MC 2020 will be a single, merged structural code for new *and* existing structures
- It has to present more general and more rational models, removing all heritage from previous empirical design rules (MC2010 was an important step forward, but further steps are possible, and needed)
- It will be an operational model code and oriented towards practical needs
- It will recognize the needs of engineering communities around the world. MC 2020 has to be a real International Code.

1ST GENERATION



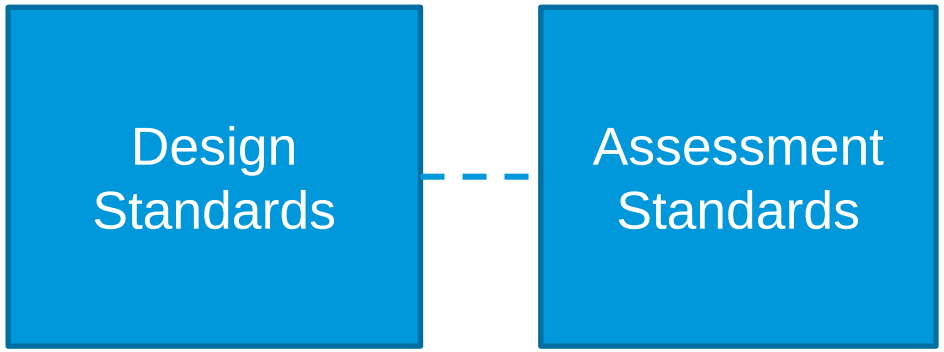
Issues:

- Failure to recognise differences between design and assessment
- Typically results in conservative assessment results
- Insufficient account taken of actual materials, detailing and tolerances

Courtesy of Steve Denton

WSP | PARSONS BRINCKERHOFF

2ND GENERATION



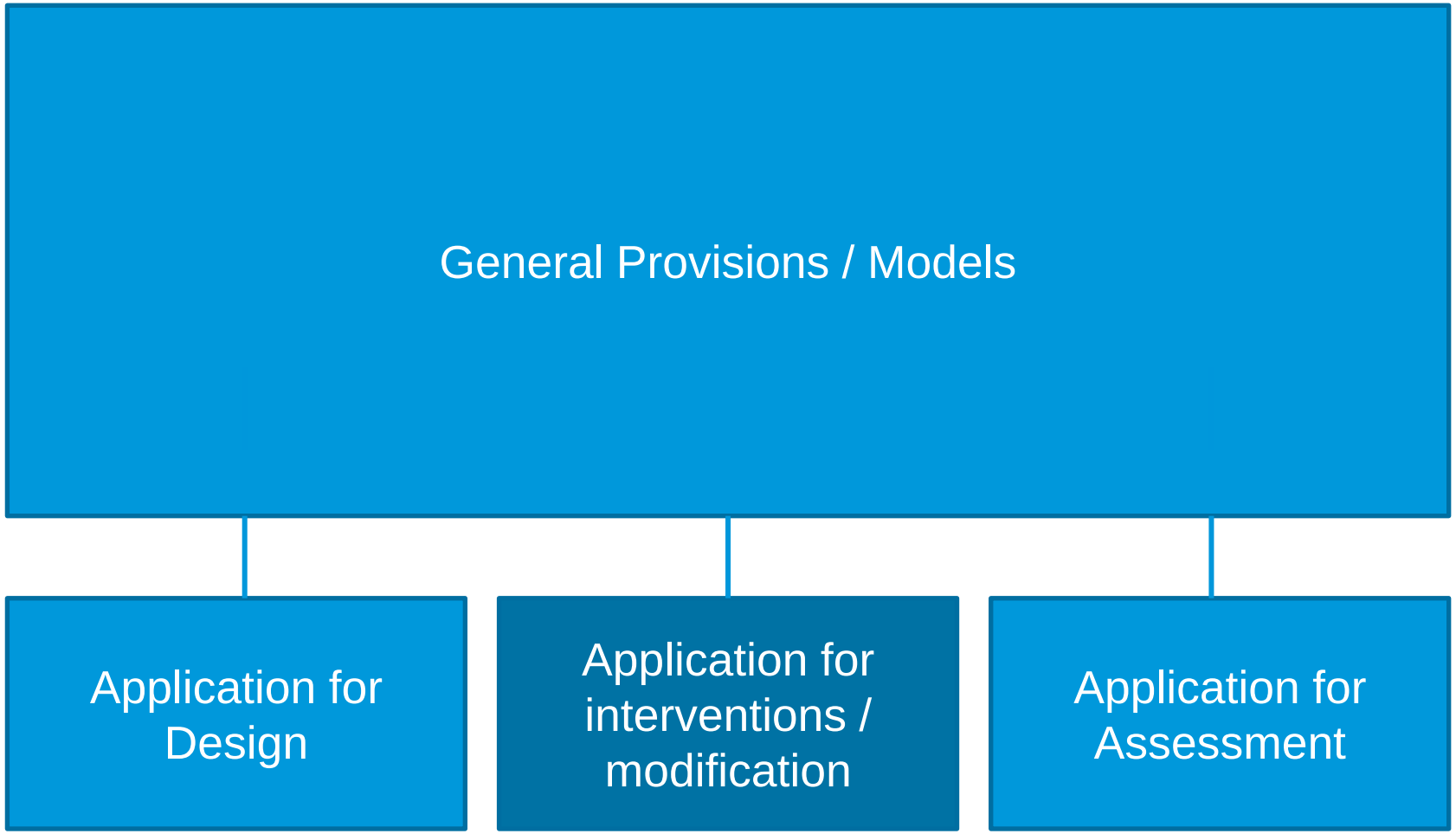
Issues:

- Duplication of content
- Omission of content
- Problematic for interventions (modification of existing structures)

Courtesy of Steve Denton

WSP | PARSONS BRINCKERHOFF

FUTURE GENERATION – SUCCESS?

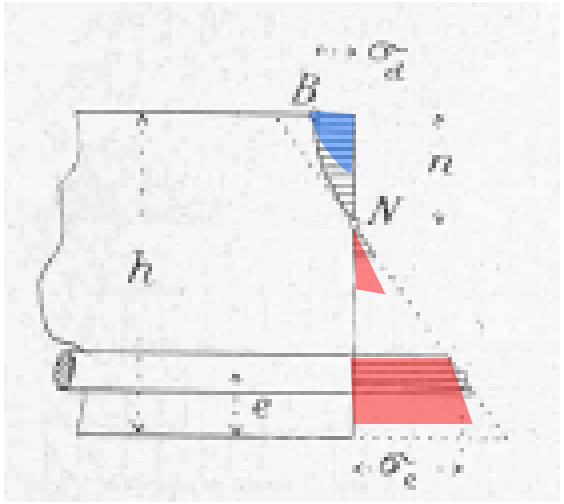


Courtesy of Steve Denton

WSP | PARSONS BRINCKERHOFF

- MC 2020 will be a single, merged structural code for new *and* existing structures
- It has to present more general and more rational models, removing all heritage from previous empirical design rules (MC2010 was an important step forward, but further steps are possible and needed)
- It will be an operational model code and oriented towards practical needs
- It will recognize the needs of engineering communities around the world. MC 2020 has to be a real International Code.

Mechanical models vs. empirical equations, the case of bending



Ritter, W., 1899, *Die Bauweise Hennebique*, Schweizerische Bauzeitung, Zurich

Courtesy of Aurelio Muttoni

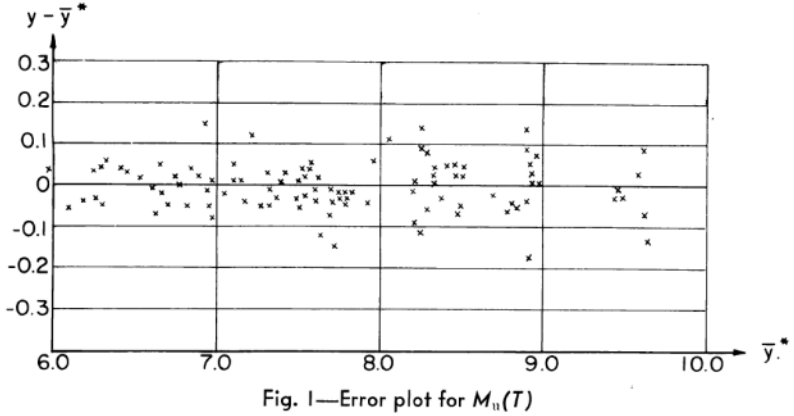


Fig. 1—Error plot for $M_u(T)$

$$M_R = 0.431 \cdot b \cdot d^2 \cdot \rho^{0.75} \cdot f_y^{0.9} \cdot f_c^{0.1} \text{ (psi, in)}$$

Zsutty T.C., *Ultimate Strength Behaviour Study by* ***Regression Analysis of Beam Test Data***, ACI Structural Journal, May 1963

Mechanical models vs. empirical equations, the case of bending

Figure 7.3-1 shows the possible range of strain distributions for concrete, reinforcing steel and prestressing steel. In the figure, the following limits are shown:

A = reinforcing strain limit;

B = concrete compression limit; and

C = concrete pure compression strain limit.

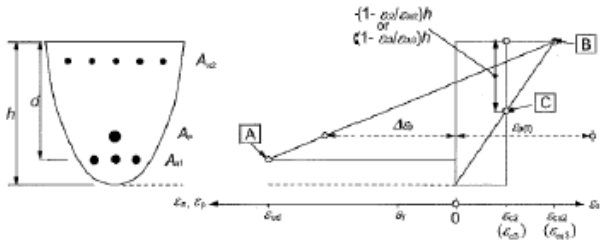


Figure 7.3-1: Possible strain distributions in the ultimate limit state.

7.3.2 Bending with and without axial force

7.3.2.1 Beams, columns and slabs

This sub-clause applies to undisturbed areas of beams, slabs and similar types of members for which sections remain approximately plane before and after loading. The discontinuity regions of beams and other members, where plane sections do not remain plane, may be designed and detailed according to sub-clause 7.3.6.

When determining the ultimate bending resistance of reinforced or prestressed concrete cross-sections, the following assumptions are made:

- plane sections remain plane;
- the strain in bonded reinforcement or bonded prestressing tendons, whether in tension or in compression, is the same as that in the surrounding concrete;
- the tensile strength of the concrete is ignored;
- the stresses in the concrete are derived from stress-strain relations for the design of cross-sections as given in sub-clause 7.2.3.1.5;
- the stresses in the reinforcing and prestressing steel are derived from the design curves in sub-clause 7.2.3.2 and 7.2.3.3; and
- the initial strain in the prestressing tendons is taken into account when

Valid for:

-Several cross sections

-With axial force

-With prestressing

-Several reinforcement layers

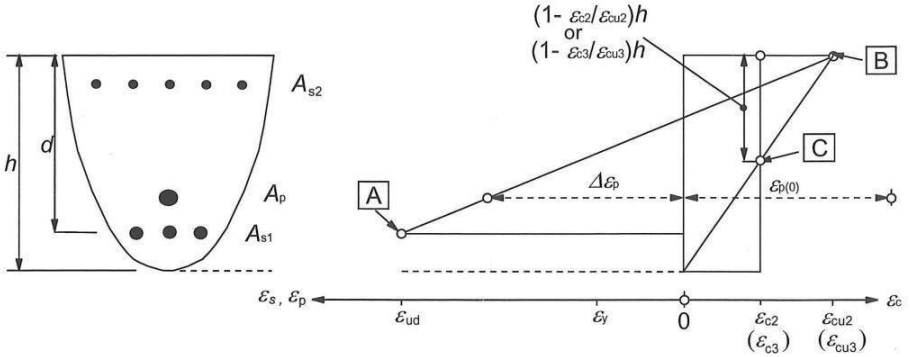
-Different concrete types

-Can be easily adapted for unforeseen cases (non-metallic reinforcement, …)

$$M_R = 0.431 \cdot b \cdot d^2 \cdot \rho^{0.75} \cdot f_y^{0.9} \cdot f_c^{0.1}$$

Courtesy of Aurelio Muttoni

CONCRETE



EXISTING CONCRETE						
fck	17	20	90	120	150	250
DESIGN CONCRETE						
fck	17	20	90	120	150	250
FIBRE REINFORCED CONCRETE (FRC)						
fck	17	20	90	120	150	250
UHPFRC						
fck	17	20	90	120	150	250

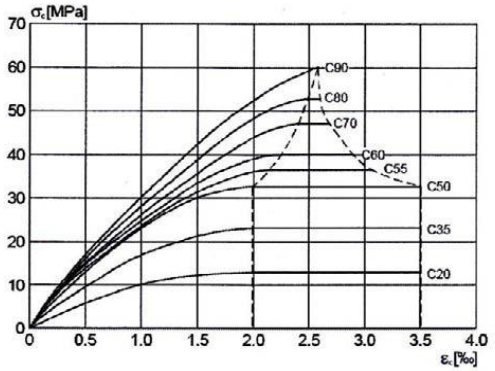


Figure 7.2-7: Design stress strain relations for various concrete strength classes (parabola-rectangle) for γ_C = 1.5

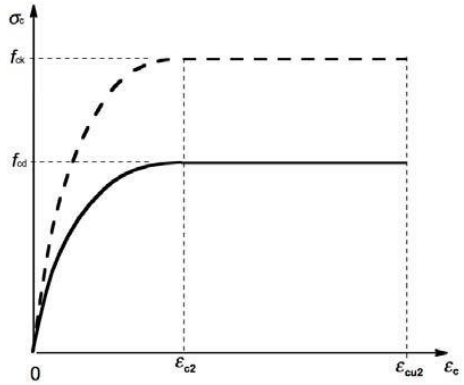
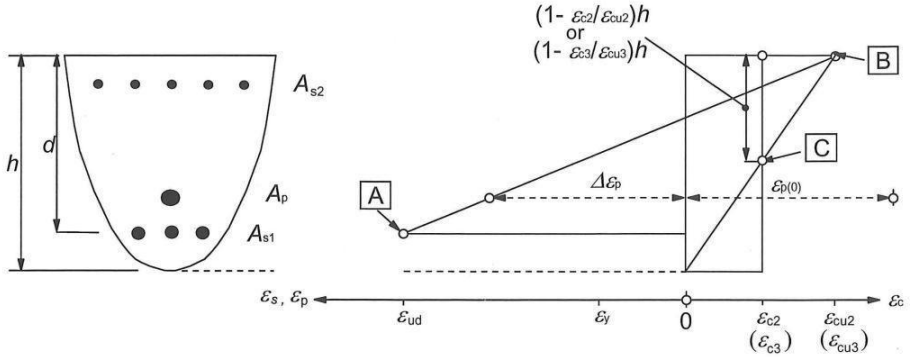


Figure 7.2-9: Parabola-rectangle diagram for concrete in compression

CONCRETE



EXISTING CONCRETE						
fck	17	20	90	120	150	250
NEW CONCRETE						
fck	17	20	90	120	150	250
FIBRE REINFORCED CONCRETE (FRC)						
fck	17	20	90	120	150	250
						UHPFRC
fck	17	20	90	120	150	250

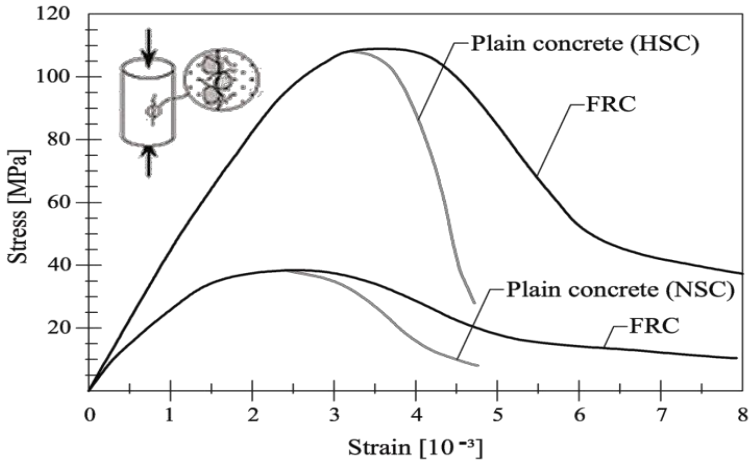
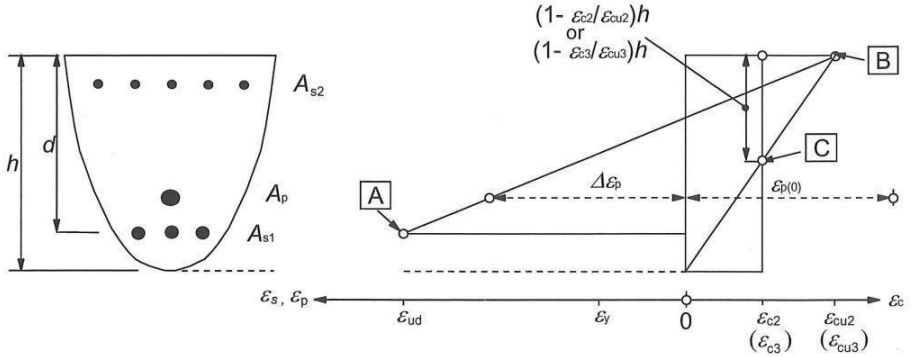


Figure 5.6-3: Main differences between plain and fibre reinforced concrete having both normal and high strength under uniaxial compression

CONFINED CONCRETE FOR SEISMIC LOADS



EXISTING CONCRETE						
fck	17	20	90	120	150	250
NEW CONCRETE						
fck	17	20	90	120	150	250
FIBRE REINFORCED CONCRETE (FRC)						
fck	17	20	90	120	150	250
UHPFRC						
fck	17	20	90	120	150	250

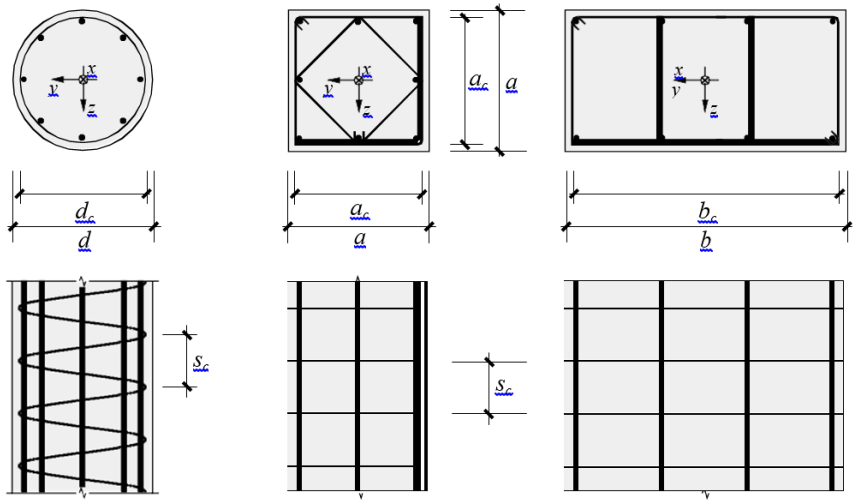
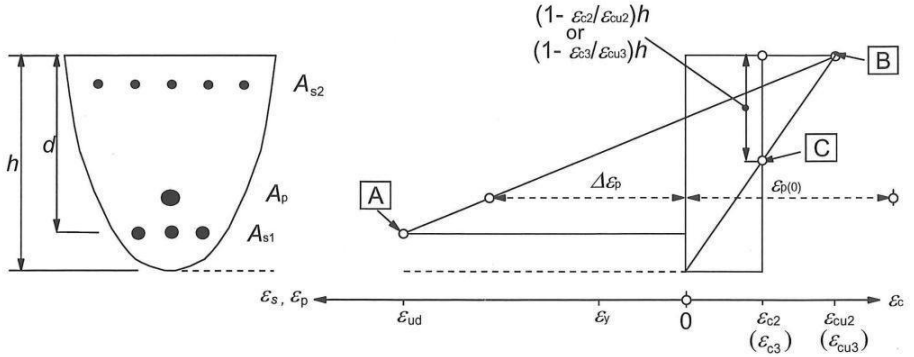


Figure 7.2-13: Compression members with confining reinforcement

CONCRETE UNDER DIFFERENT TEMPERATURES DURING FIRE



EXISTING CONCRETE						
fck	17	20	90	120	150	250
NEW CONCRETE						
fck	17	20	90	120	150	250
FIBRE REINFORCED CONCRETE (FRC)						
fck	17	20	90	120	150	250
						UHPFRC
fck	17	20	90	120	150	250

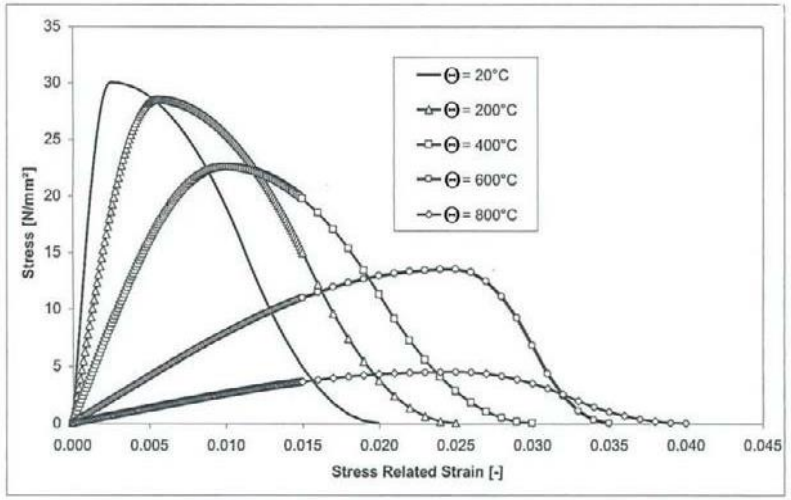
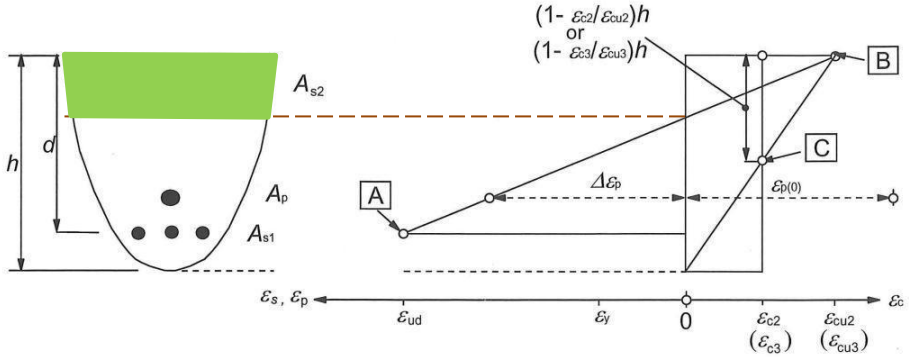


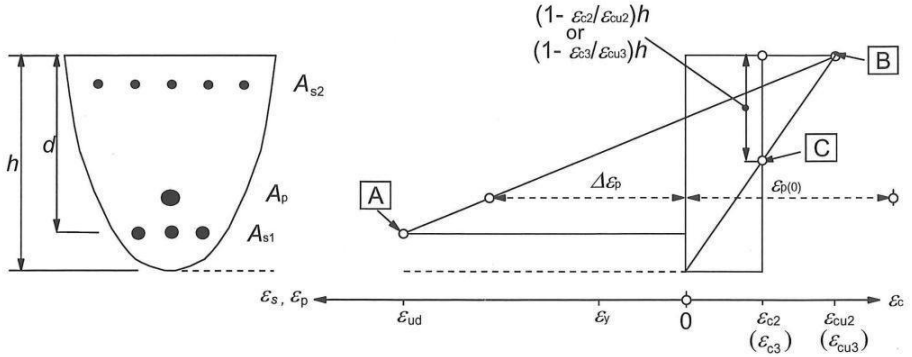
Figure 7.5-3: Example of stress-strain relationships of concrete under compression at elevated temperatures

DAMAGED CONCRETE



EXISTING CONCRETE						
fck	17	20	90	120	150	250
NEW CONCRETE						
fck	17	20	90	120	150	250
FIBRE REINFORCED CONCRETE (FRC)						
fck	17	20	90	120	150	250
					UHPFRC	
fck	17	20	90	120	150	250

REINFORCING STEEL



EXISTING REINFORCING STEEL		
fyd	200	600

REINFORCING STEEL		
fyd	400	600

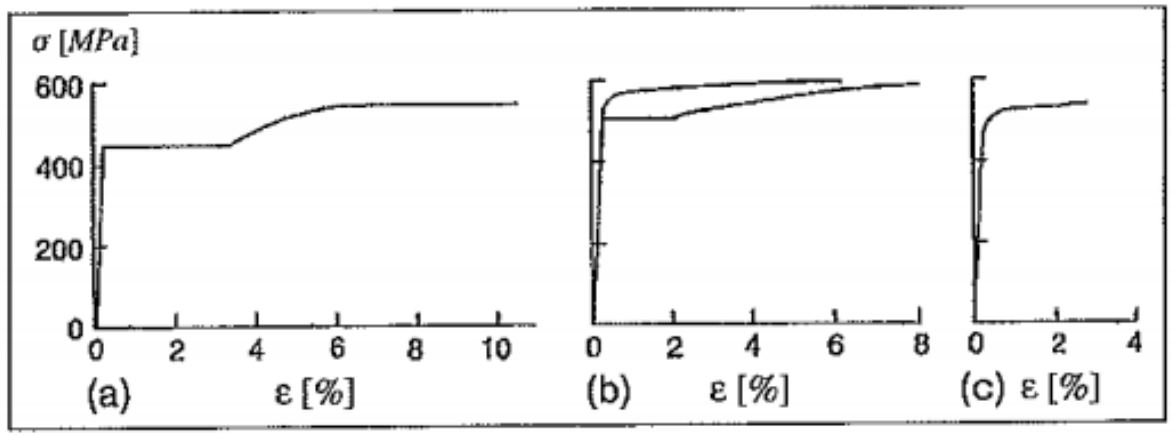
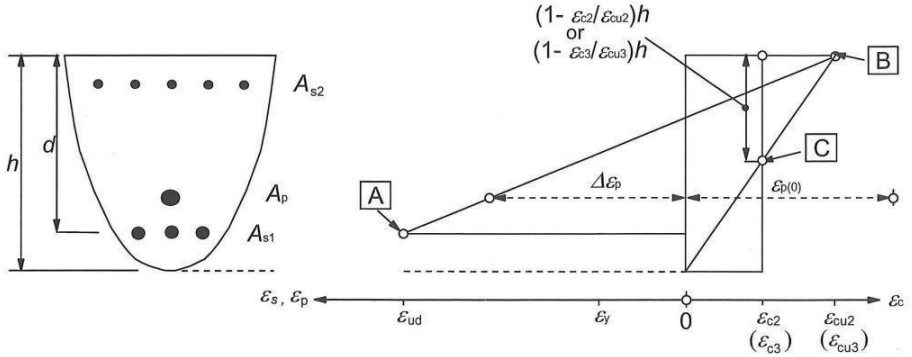


Figure 5.2-1: Stress-strain relationships of reinforcing steel: (a) hot-rolled bars; heat-treated bard; micro-alloyed bars, (b) low carbon, heat-treated bars (lower curve): cold-worked bars (upper curve); (c) cold-worked wires.

PRESTRESSING STEEL



EXISTING PRESTRESSING STEEL			
fyp	1700	2000	2500
PRESTRESSING STEEL			
fyp	1700	2000	2500

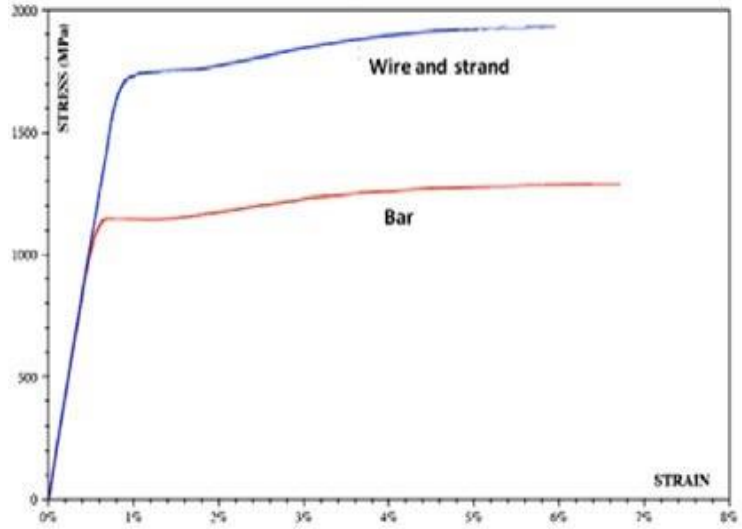
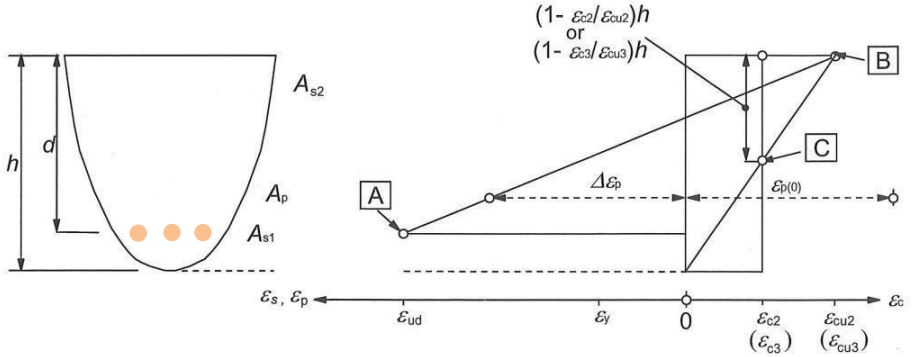


Figure 5.3-1: Typical stress-strain diagrams for prestressing steel

NON-METALLIC REINFORCEMENT / FRP REINFORCEMENT



NON-METALLIC REINFORCEMENT / FRP		
fck	1000	2500

	CFRP	GFRP	AFRP
Tensile strength f_f [MPa]	600-3000	400-1600	600-2500
Modulus of elasticity E_f [GPa]	80-500	30-60	30-125
Ultimate strain ε_{fu} [%]	0.5-1.8	1.2-3.7	1.8-4.0

Table 5.5-1: Tensile properties of FRP reinforcement

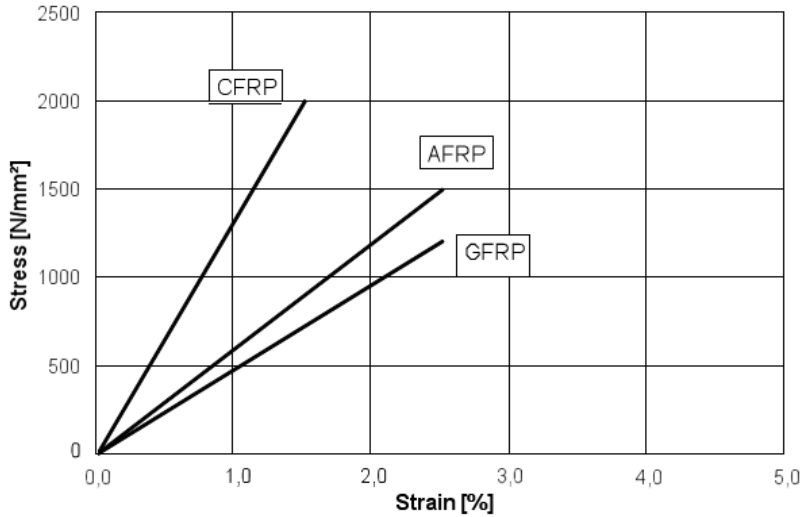
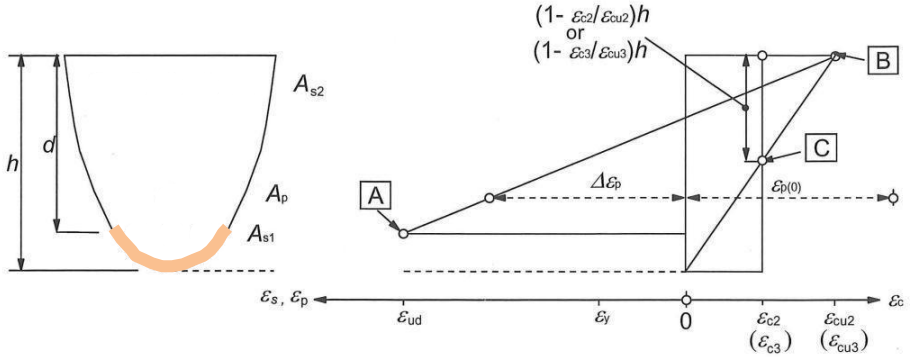


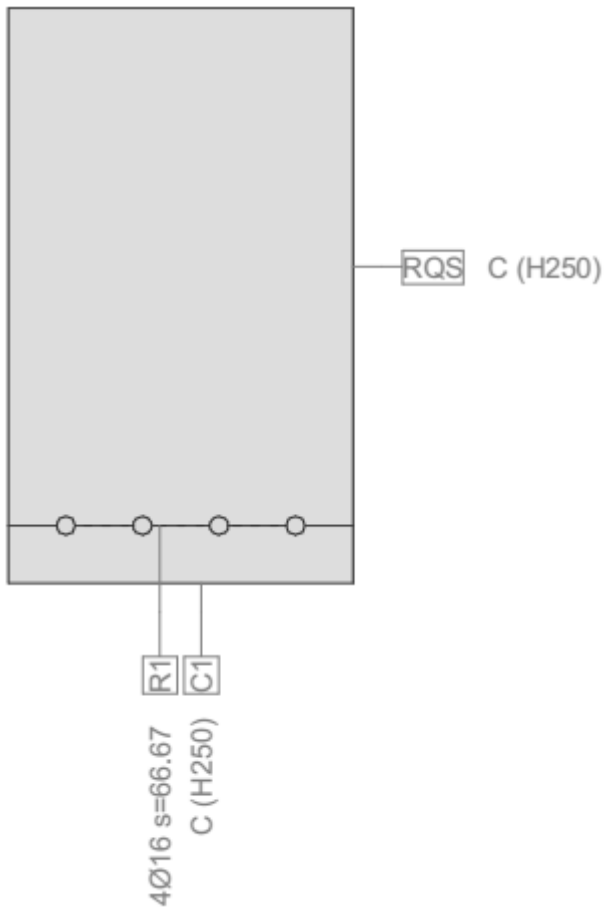
Figure 5.5-1: Stress-strain diagram of non-metallic reinforcement in the principal fibre direction

NON-METALLIC REINFORCEMENT / FRP REINFORCEMENT

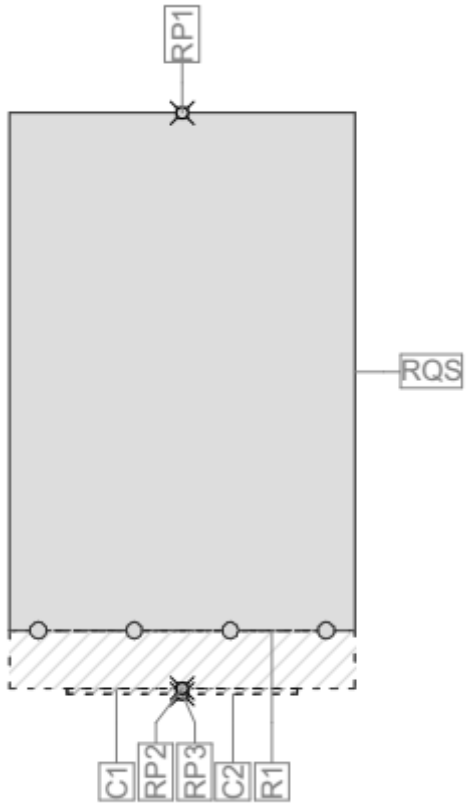


NON-METALLIC REINFORCEMENT / FRP		
fck	1000	2500

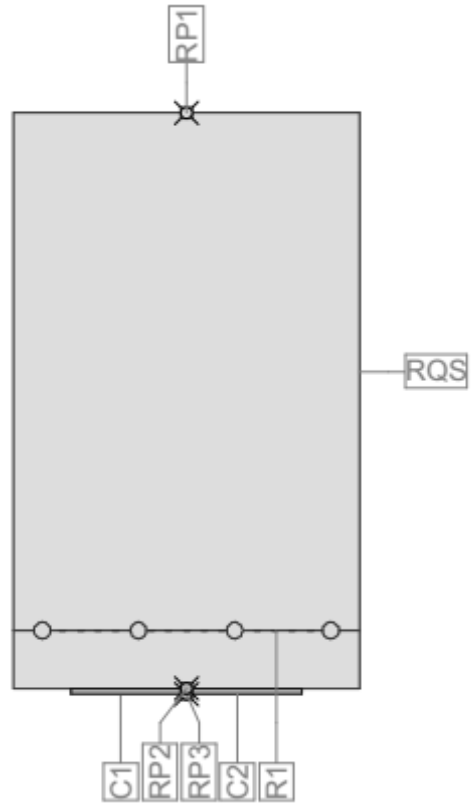
Cross-section INITIAL
(H250, AEH500)



Cross-section SEGUNDA, Variant oxidada
(H250, AE355, AEH500)

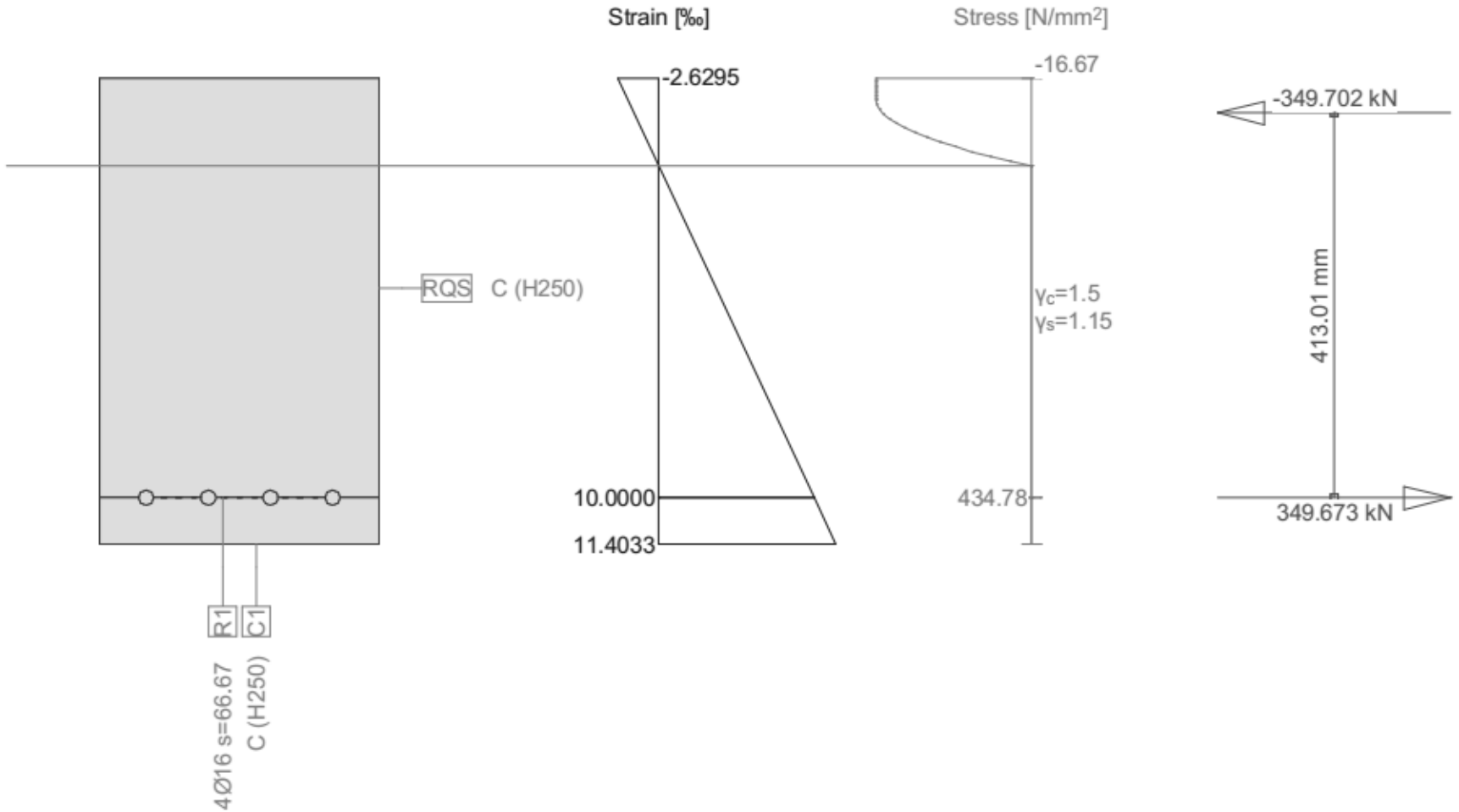


Cross-section SEGUNDA,
(H250, AE355, AEH500)



Cross-section INICIAL (H250;AEH500): Efficiency My=142.000; eff(M,N) = 0.98 OK

Scale 1 :10.0

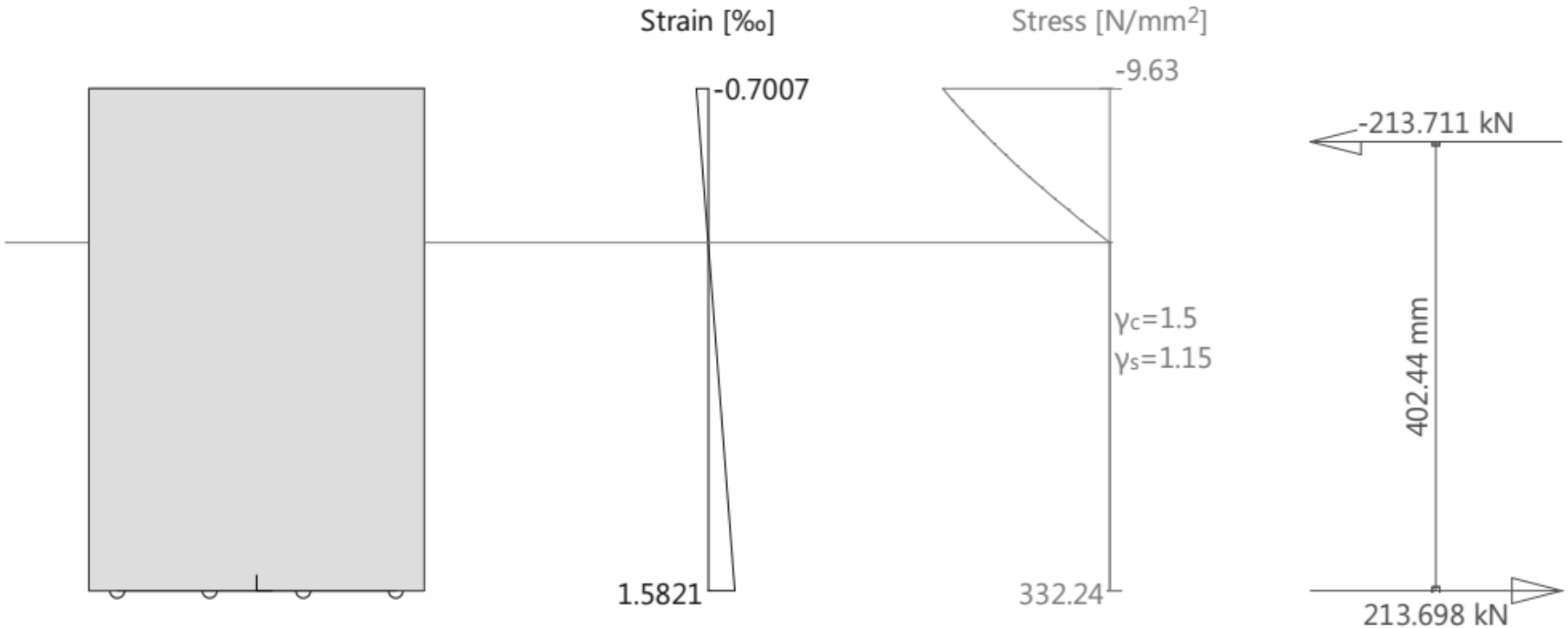


Action forces / Efficiency: eff(M,N) = 0.98 OK

No.	AP	P	Bending and axial force N [kN]	M_y [kNm]	M_z [kNm]	eff(M,N) [-]	Shear forces and torsion V_y [kN]	V_z [kN]	T [kNm]	eff(V,T) [-]	Complete CS eff(M,N,V,T) [-]
1	AP4		0	142.000	-	0.98					

\- : Calculation with uniaxial bending (neutral axis is horizontal)!!

Stress analysis Cross section (Girder): SEGUNDA , Variante: OXIDADA Scale 1 :8.2



Action forces / Loading history - calculation with loading steps, (in-)active parts,

No.	AP	P	Bending and axial force N [kN]	M_y [kNm]	M_z [kNm]	Shear forces and torsion V_y [kN]	V_z [kN]	T [kNm]	Remarks -
1									
2	AP4		0	86.000	0				Set inactiv

1 : Set inactiv: C2,C1

Stress analysis Cross section (Girder): SEGUNDA

Scale 1 :9.2

Action forces / Loading history - calculation with loading steps, (in-)active parts,

No.	AP	P	Bending and axial force N [kN]	M_y [kNm]	M_z [kNm]	Shear forces and torsion V_y [kN]	V_z [kN]	T [kNm]	Remarks -
1 2	AP4		0	86.000	-				Set inactiv
3 4	AP4		0	114.000	-				Set activ

- MC 2020 will be a single, merged structural code for new *and* existing structures
- It has to present more general and more rational models, removing all heritage from previous empirical design rules (MC2010 was an important step forward, but further steps are possible, and needed)
- It will be an operational model code and oriented towards practical needs
- It will recognize the needs of engineering communities around the world. MC 2020 has to be a real International Code.

7.3 Verification of structural safety (ULS) for predominantly static loading

7.3.1 General

This subsection gives methods of verifying that, for a structure as a whole and for its component parts, the probability of an ultimate limit state exceeding the resistance of critical regions is acceptably small.

The determination of the partial safety coefficients and action effects is to be undertaken in accordance with the principles set out in chapter 4.

7.3.2 Bending with and without axial force

7.3.2.1 Beams, columns and slabs

This subsection applies to undisturbed areas of beams, slabs and similar types of members for which sections remain approximately plane before and after loading. The discontinuity regions of beams and other members, where plane sections do not remain plane, may be designed and detailed according to subsection 7.3.6.

Figure 7.3-1 shows the possible range of strain distributions for concrete, reinforcing steel and prestressing steel. In the figure, the following limits are shown:

A = reinforcing strain limit;
B = concrete compression limit;
C = concrete pure compression strain limit.

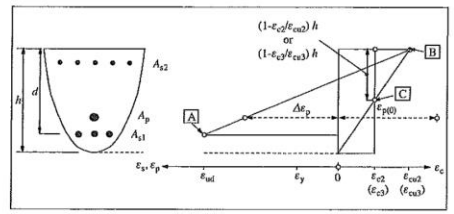


Figure 7.3-1: Possible strain distributions in the ultimate limit state

When determining the ultimate bending resistance of reinforced or prestressed concrete cross-sections, the following assumptions are made:

- plane sections remain plane;
- the strain in bonded reinforcement or bonded prestressing tendons, whether in tension or in compression, is the same as that in the surrounding concrete;
- the tensile strength of the concrete is ignored;
- the stresses in the concrete are derived from stress–strain relations for the design of cross-sections as given in subsection 7.2.3.1.5;
- the stresses in the reinforcing and prestressing steel are derived from the design curves in subsections 7.2.3.2 and 7.2.3.3;
- the initial strain in the prestressing tendons is taken into account when assessing the stresses in the tendons.

For cross-sections with symmetrical reinforcement loaded by a compression force, the minimum eccentricity should be taken as $e_0 = h/30$ but not less than 20 mm, where h is the depth of the section.

7.3.2.2 Shells

Shell elements may be modelled as comprising three layers (Figures 7.3-2 and 7.3-3). The outer layers provide resistance to the in-plane effects of both the bending and the in-plane axial loading, while the core layer provides a shear transfer between the outer layers.

The action effects of the applied loads are expressed as eight components, three moments per unit width, three axial forces per unit width and two shear forces per unit width in directions parallel to the orthogonal reinforcement. The stress resultants m_x, m_y, m_{xy}, n_x, n_y, n_{xy}, v_x, v_y produce the following forces per unit width on the element:

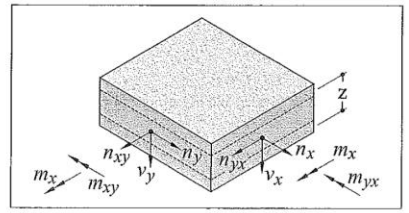


Figure 7.3-2: Three-layer plate model and stress resultants

The subscript notations *inf* and *sup* refer to the inferior and superior faces of the element. The inferior face is the tensile face for an element in positive bending.

$$n_{x\,inf,sup} = \frac{n_x}{2} \pm \frac{m_x}{z} + \frac{v_x^2}{2v_o}\cot\theta \qquad (7.3\text{-}1)$$

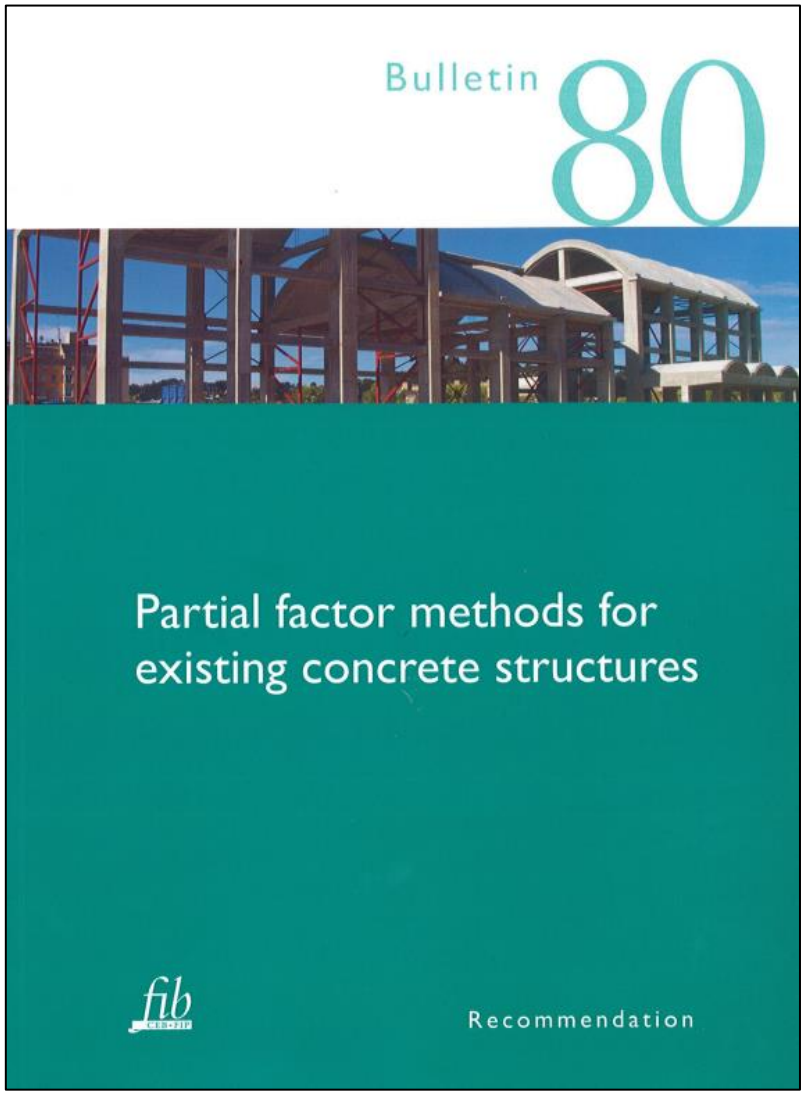


Table of contents

Foreword iii

Introduction iv

1 Scope of application 1

2 List of symbols and definitions 2
- 2.1 List of symbols 2
- 2.2 Definitions 4

3 Background and motivation for alternative target reliability levels for existing structures 7
- 3.1 Introduction 7
- 3.2 Economic considerations 9
- 3.3 Human safety considerations 14
- 3.4 Combination of economic and human safety considerations 21

4 Partial factor methods for existing concrete structures 26
- 4.1 General framework 26
- 4.2 The design value method 37
- 4.3 The adjusted partial factor method (APFM) 49

5 Numerical validation 73
- 5.1 Model uncertainty factors 73
- 5.2 Actions 73
- 5.3 Resistance 76
- 5.4 Reliability analysis 79

6 Discussion 85
- 6.1 Comparison of alternative approaches 85
- 6.2 Application limits 87
- 6.3 Note on combinations of variable actions 93

7 Application example 93
- 7.1 Introduction 93
- 7.2 Input data for the application example 94
- 7.3 Determination of partial factors for the assessment of the existing structure 96
- 7.4 Determination of the load-bearing capacity 99

8 References 100

Joost Walraven*
Agnieszka Bigaj

DOI: 10.1002/suco.201100025

The 2010 *fib* Model Code for Concrete Structures: a new approach to structural engineering

The fib Model Code is a recommendation for the design of reinforced and prestressed concrete which is intended to be a guiding document for future codes. Model Codes have been published before, in 1978 and 1990. The draft for fib Model Code 2010 was published in May 2010. The most important new element in this Model Code is "Time" in the sense of service life. Additionally, the Model Code contains an extended state-of-the-art chapter on the structural materials concrete and steel but regards non-metallic reinforcement and fibres as reinforcement as well. Many loading conditions are considered, ranging from static loading to non-static loading, considering earthquake, fatigue and impact/explosion. Five methods are offered to verify structural safety. Attention is given to verification of limit states associated with durability, robustness and sustainability. Finally, verification assisted by numerical methods and by testing is considered. Other elements that are links in the chain of life cycle design are construction and conservation. In the part on conservation the conservation strategy is treated in combination with conservation management, condition survey and assessment, and evaluation and decision-making.

Keywords: Concrete , Concrete Structures, Recommendations, *fib*, Future developments

1 Past and future of the Model Code for Concrete Structures

1.1 History of the Model Code for Concrete Structures

Structural design has been an important societal activity from the beginning of mankind. The need to protect people against the influence and variation of climate in an environment where they feel safe and which satisfies certain functional demands has given work to architects and builders for centuries. Structural concepts have been subjected to changes in views regarding to safety, functionality and aesthetics, Fig. 1 and 2.

In order to make sure that the users of structures are not endangered by insufficient safety of the structure, building codes were already around even in ancient times. Those codes were mostly developed on a national basis and showed considerable differences. In the 20th century in Europe, increasing interest was noted in exchanging views on structural design and in discussing results from investigations and experiences.

The Euro-International Concrete Committee (CEB – Comité Euro-International du Béton) was founded in 1953. The founders, *Balency-Béarn*, *Nennig*, *Base*, *Rüsch*, *Torroja* and *Wästlund*, had the vision that post-war Europe needed a common approach in concrete design and construction. Their greatest concern was the enormous disparity between codes in Europe and their very limited scientific basis. Therefore, the main goal of CEB has from

Fig. 1. Pons Fabricius in Rome, built 62 BC

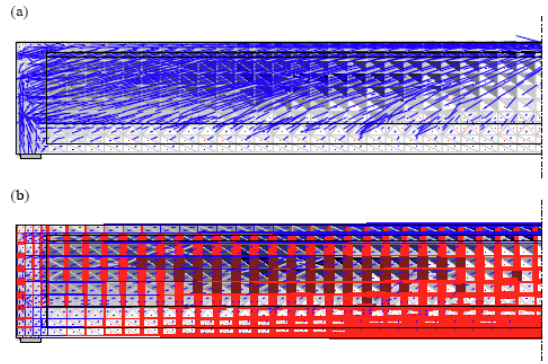
Fig. 2. Zaragosa Bridge Pavilion, Zaha Hadid, 2008

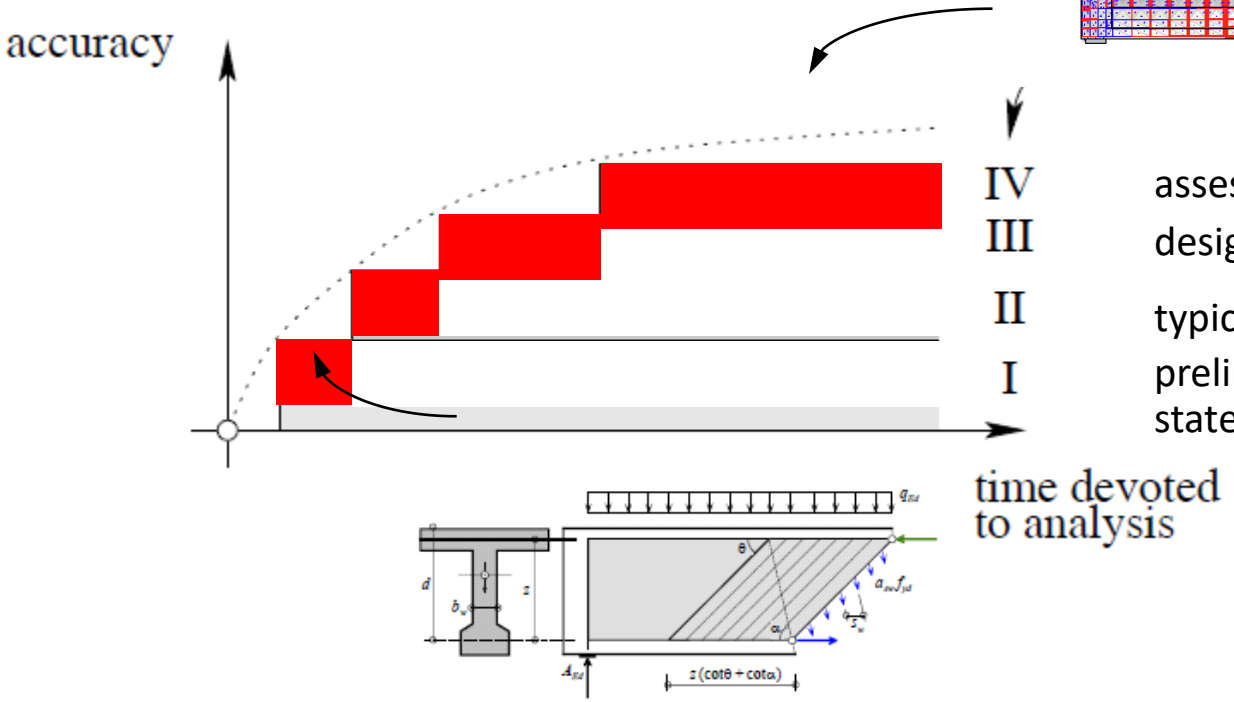
* Corresponding author: J.C.Walraven@tudelft.nl

Submitted: 31 July 2011
Accepted for publication: 2 August 2011

© 2011 **Ernst & Sohn** Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin

Levels of approximation approach (MC 2010)





assessment of critical existing structures

design of special cases

typical design

preliminary design, non governing limit state

Muttoni, A., *Introduction to SIA 262 code*, Documentation SIA D 0182, Zürich, 2003

Muttoni A., Fernández Ruiz M. , *Levels-of-approximation approach in codes of practice* , Structural Engineering International, 2012

Muttoni A., Fernández Ruiz M., *The levels-of-approximation approach in MC 2010: application to punching shear provisions*, Structural Concrete, 2012

Courtesy of Aurelio Muttoni

- MC 2020 will be a single, merged structural code for new *and* existing structures
- It has to present more general and more rational models, removing all heritage from previous empirical design rules (MC2010 was an important step forward, but further steps are possible, and needed)
- It will be an operational model code and oriented towards practical needs
- It will recognize the needs of engineering communities around the world. MC 2020 has to be a real International Code.

MC2020 Initiative – Global involvement

Interactive Session on MC2020 - Maastricht, 14 June 2017

PCI Workshop Denver Feb 2018

JCI-*fib* Joint Workshop Japan Sept 2016

ABECE Abicic Workshop Brasil Sept 2017

Workshop Cape Town Nov 17 - 24 2016

Workshop Australia-Adelaida Oct 2017

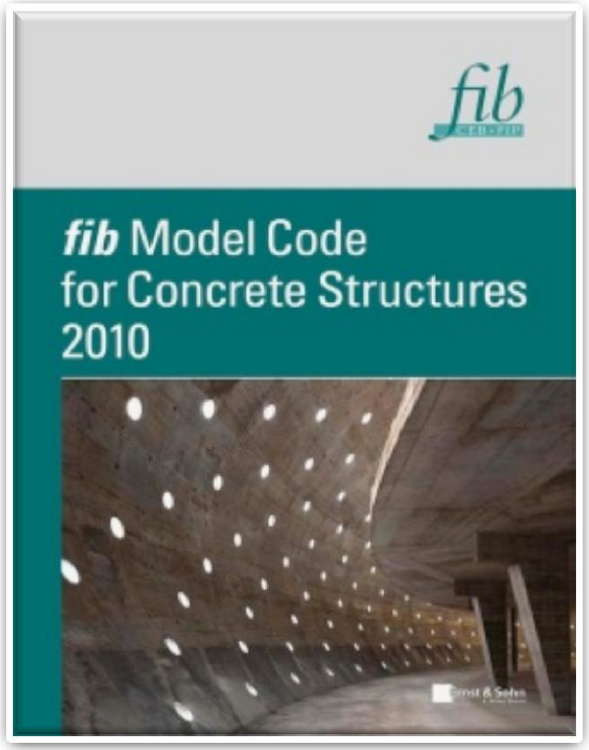
fib Latin-American Seismic Group

Chile

Mexico

Colombia

Brazil



Preface & Notations

PART I: PRINCIPLES

PART II: DESIGN INPUT DATA

PART III: DESIGN

PART VI: CONSTRUCTION

PART V: CONSERVATION AND DISMANTLEMENT

Scope & Terminology

PART I: BASIC PRINCIPLES

PART II: ACTIONS ON STRUCTURES

PART III: DESIGN INPUT DATA

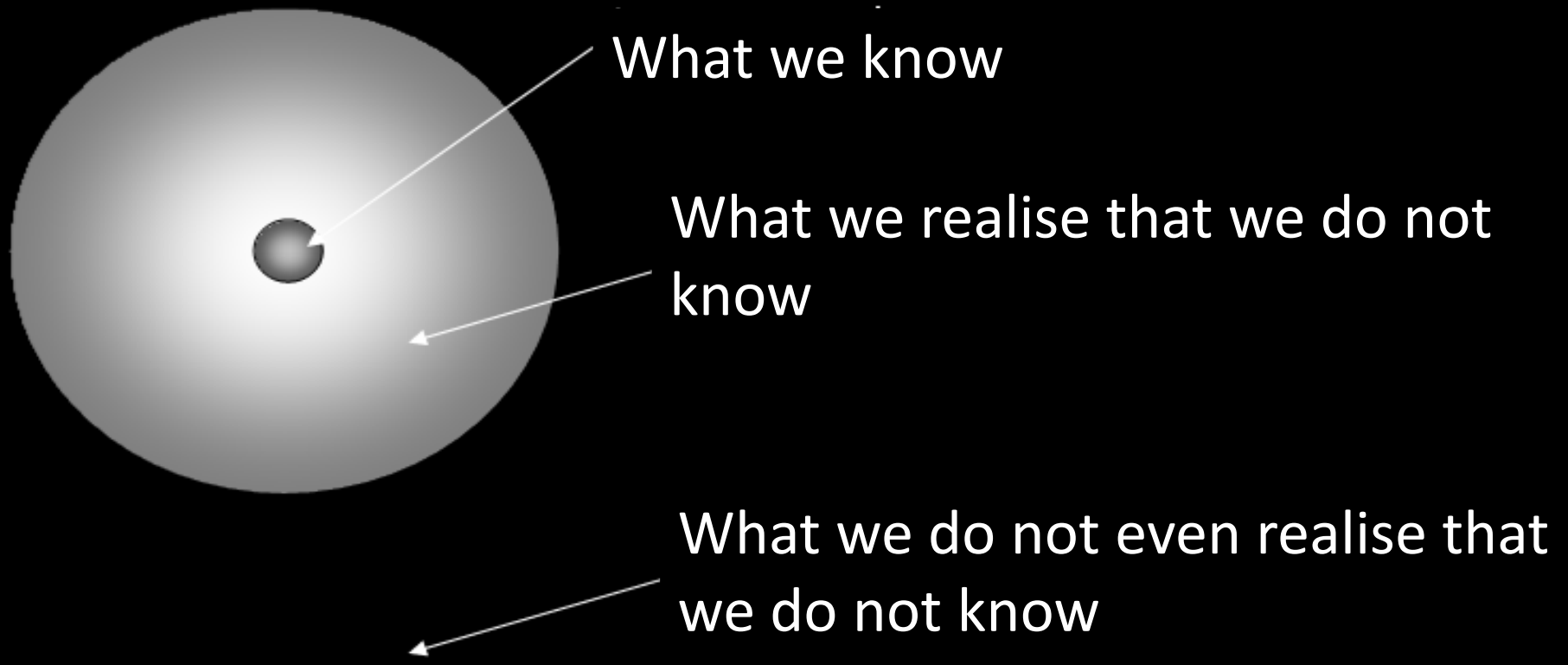
PART IV: DESIGN AND ASSESSMENT PROCEDURES

PART V: EXECUTION

PART VI: THROUGH-LIFE MANAGEMENT, DISMANTLEMENT AND REUSE

“Engineering is the art of modeling materials we do not wholly understand, into shapes we cannot precisely analyse, so as to withstand forces we cannot properly assess, in such a way that the public at large has not reason to suspect the extent of our ignorance.”

President of the Institution of Civil Engineers 1946



Consideraciones finales

Construction 1936

Rehabilitation 2000

engineering

fib Young Engineers Group

Technical visit Madrid meeting

FAKULTA STAVEBNÍ ČVUT
fib 2018 prague
The 12th fib International PhD Symposium in Civil Engineering
Prague, Czech Republic, August 29-31, 2018
fib CTU CBS

INTERNATIONAL *fib* SYMPOSIUM ON CONCEPTUAL DESIGN OF STRUCTURES

SHARE YOUR CREATIVITY WITH US

SEPTEMBER 26-28, 2019

TORROJA INSTITUTE | MADRID (SPAIN)

WWW.CONCEPTUALDESIGN2019.COM

fib CEB • FIP

ACHE Asociación Española de Ingeniería Estructural

THE *fib's* WAY OF WORKING

COM10 – First Meeting. Lausanne, 15 October 2016 at the EPFL

fib