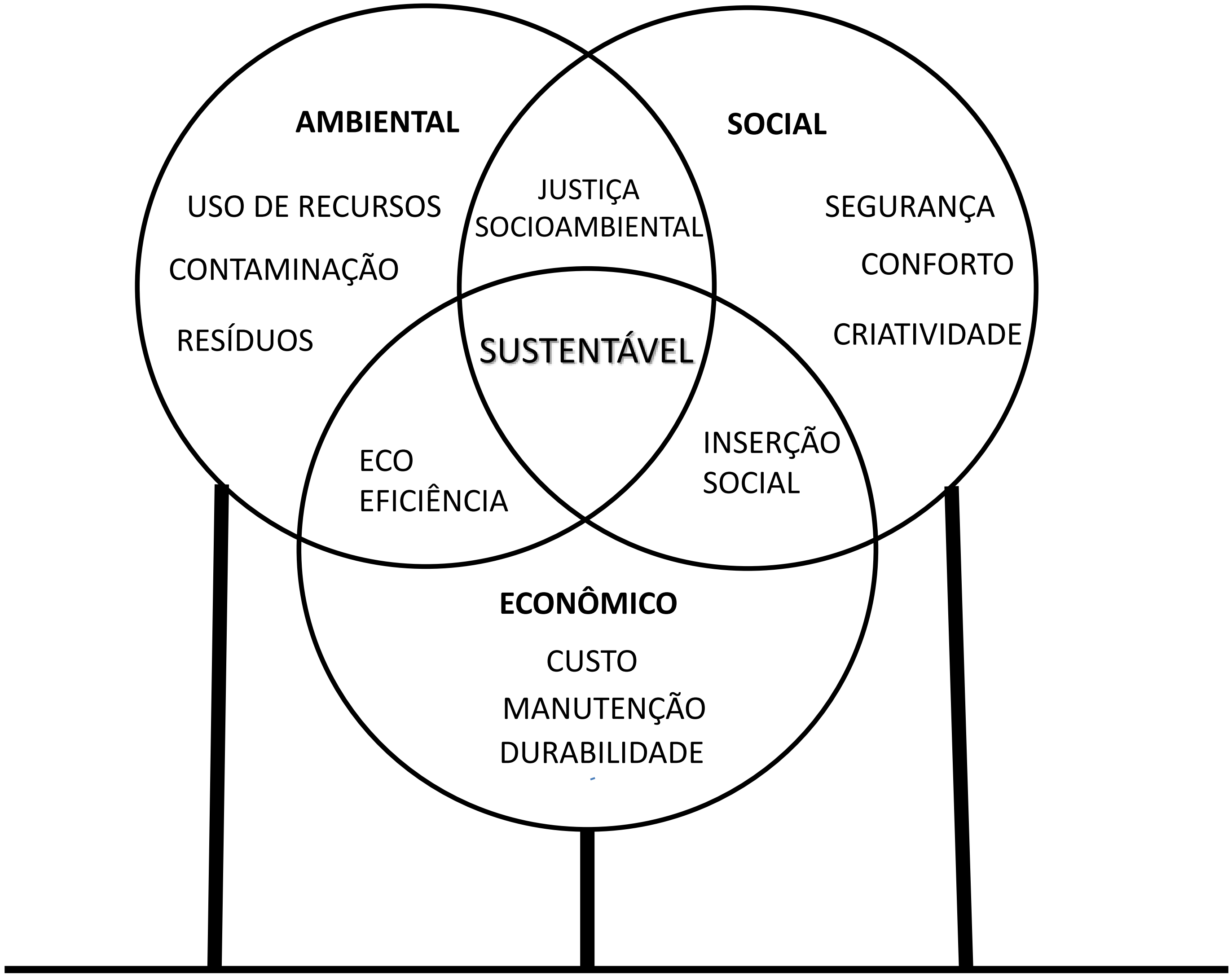
Hugo Corres Peiretti
Professor de Estruturas de Concreto na Universidade Politécnica de Madri
Vice presidente da fib
Fundador Fhecor Ingenieros Consultores

ENGENHARIA PARA UM MUNDO MAIS SUSTENTÁVEL

Desenvolvimento Sustentável atendende as necessidades presentes sem comprometer as necssidades das gerações futuras.

Our Common Future or Brundtland Report, 1987


AMBIENTAL
USO DE RECURSOS
CONTAMINAÇÃO
RESÍDUOS
SOCIAL
SEGURANÇA
CONFORTO
CRIATIVIDADE
JUSTIÇA SOCIOAMBIENTAL
SUSTENTÁVEL
ECO EFICIÊNCIA
INSERÇÃO SOCIAL
ECONÔMICO
CUSTO
MANUTENÇÃO
DURABILIDADE

Introduction

1 Introduction

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Introduction

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Para se ter uma idéia da relevância do impacto do setor da construção civil:

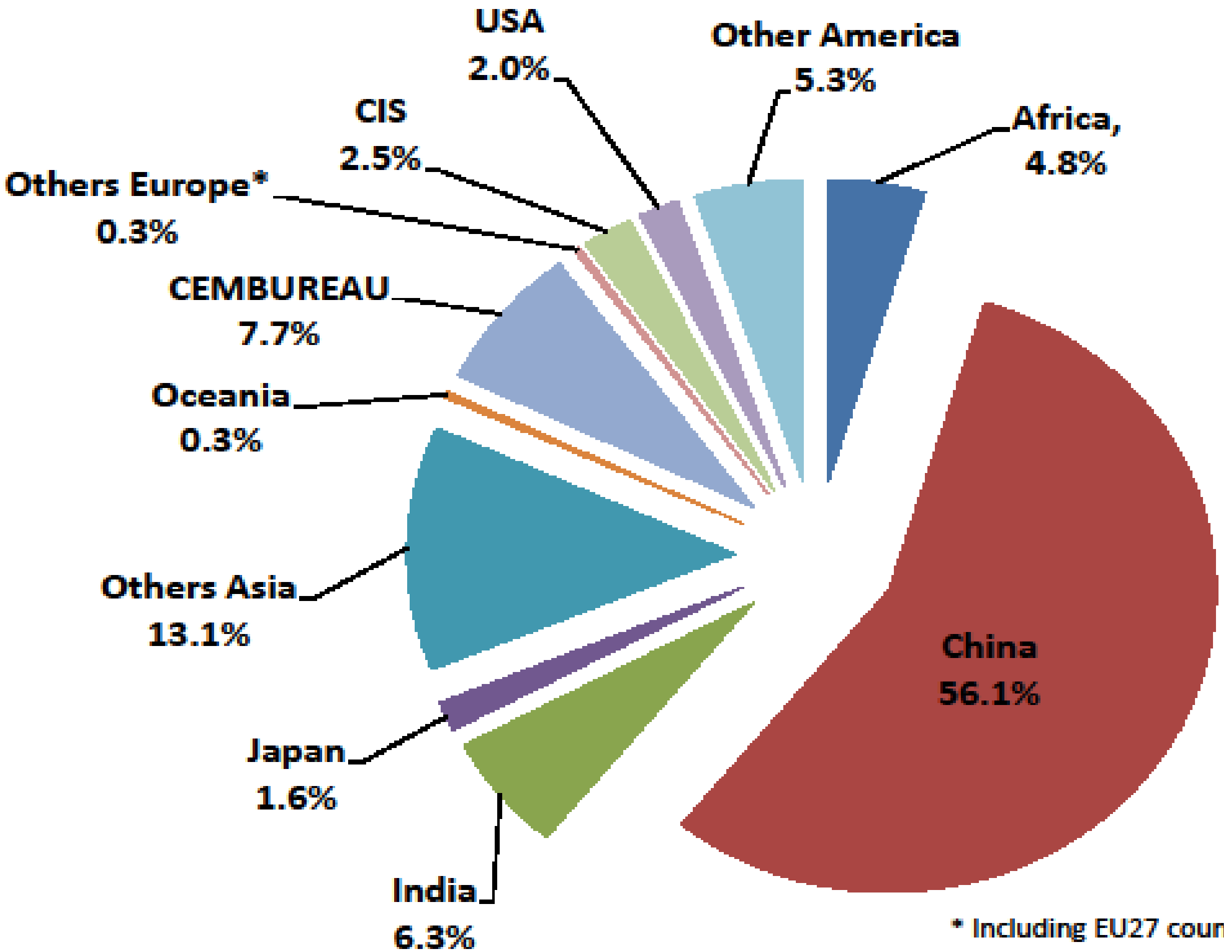
- Gera emprego para 7% da população mundial;
- Consome 40% da energida total produzida;
- Consome 50% dos recursos naturais explorados;
- Alem disso, o concreto é o material industrializado mais consumido.

Mehta, P. Kumar; MONTEIRO, Paulo J. M. Concreto: Microestrutura, Propriedades e Materiais. 2. ed. São Paulo: IBRACON, 2014.

Valdés, Adriana. De cara al siglo XXI: la arquitectura y el concreto. Construcción y Tecnología En Concreto, Col. Flórida.

Produção mundial de cimento em 2010

3,3 bilhões toneladas



* Including EU27 countries not members of CEMBUREAU

3,3 bilhões de t de cimento

60% para concreto

2 bilhões de t de cimento

320kg/m^3

6,2 bilhões de m^3 de concreto

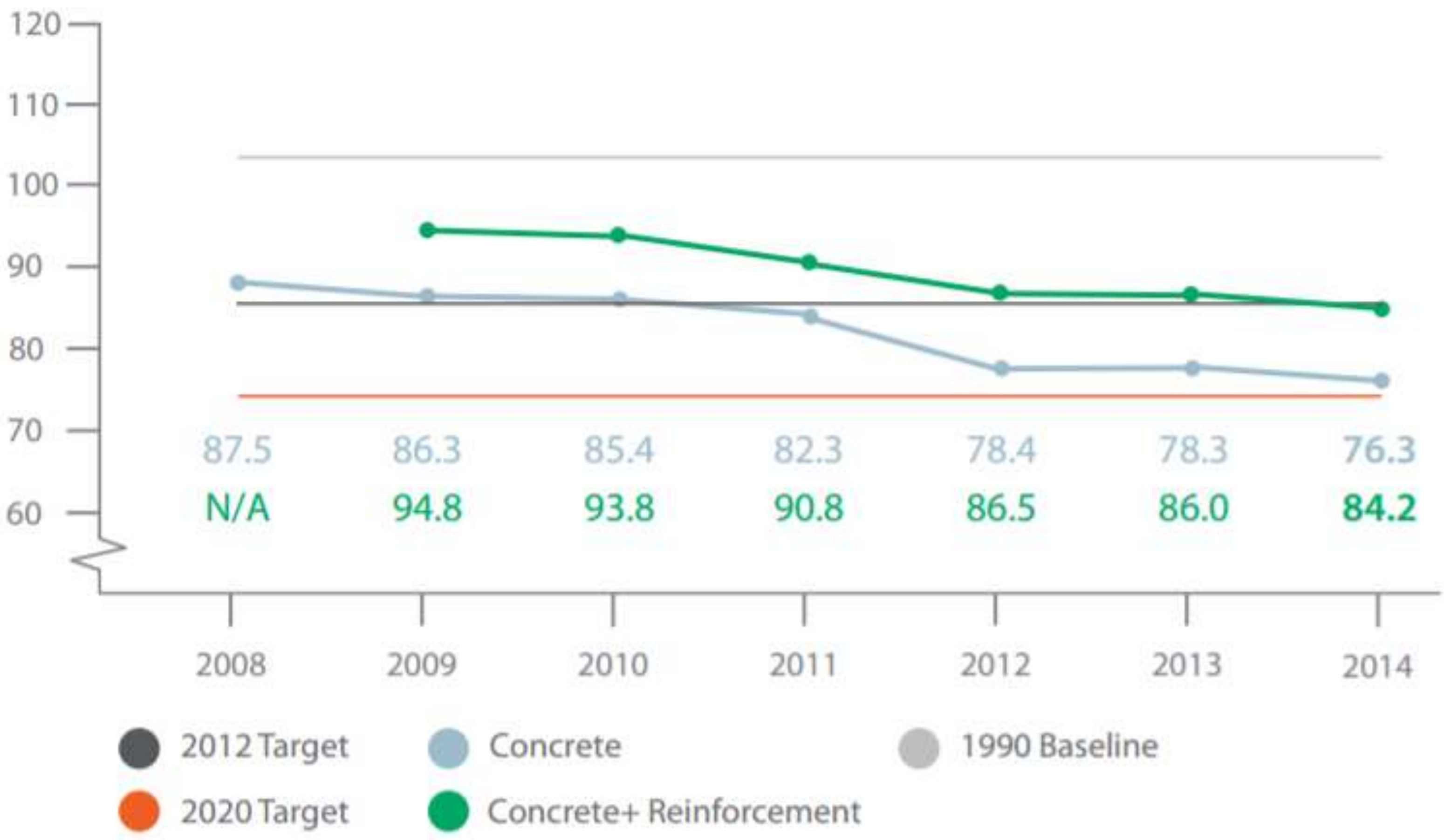
16 bilhões de t de concreto

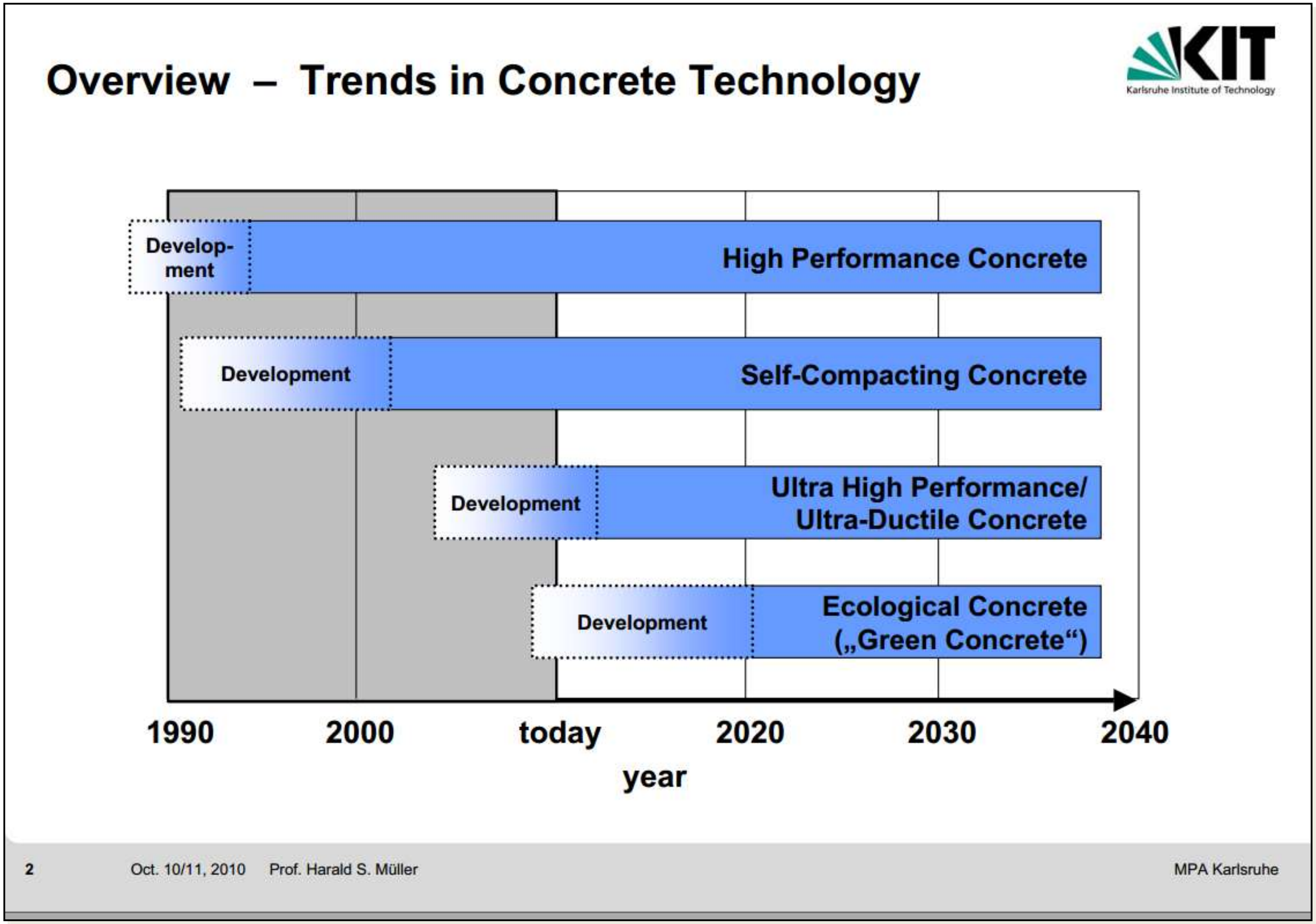
4 bilhões de m^3 de agregado

1,2 trilhões de litros de água

Paulo Helene. Concreto e Sustentabilidade das Estruturas. Workshop internacional:soluções em engenharia para obras de infraestrutura com ênfase na pré-fabricação em concreto e na sustentabilidade, Rio de Janeiro. 2012

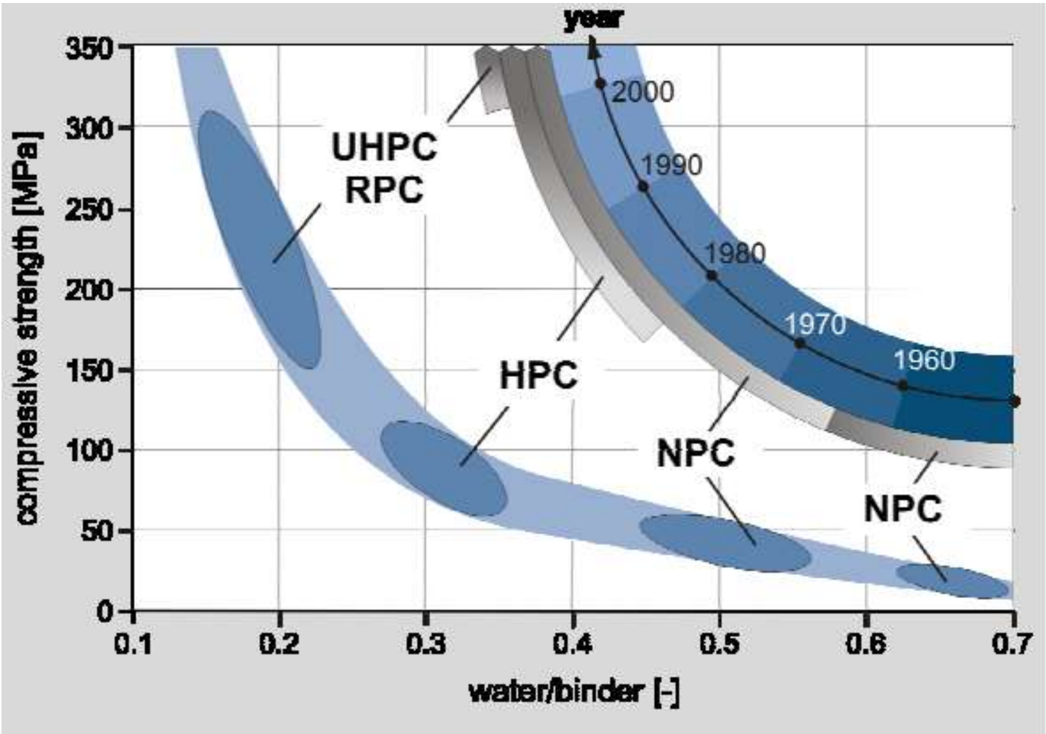
Emissão de CO_2 durante a produção (dosagem padrão) – (kg CO_2 /tonelada)





Harald Muller. New Types of High Performance Concretes – Potentials for Innovations in Concrete Constructions. ACES Workshop. Innovative Materials and Techniques in Concrete Construction. Corfu, Creece. 2010

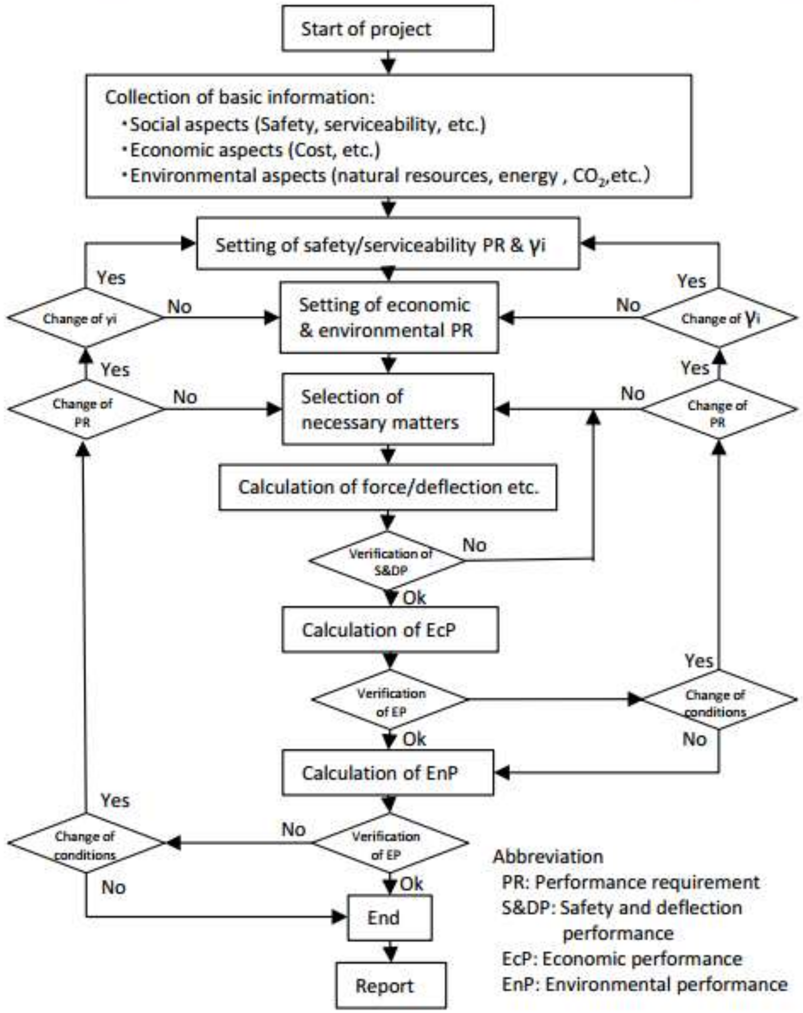
Ultra High Performance Concrete (UHPC)



first footbridge made of RPC in Sherbrooke, Canada, 1997

Harald Muller. New Types of High Performance Concretes – Potentials for Innovations in Concrete Constructions. ACES Workshop. Innovative Materials and Techniques in Concrete Construction. Corfu, Creece. 2010

Framework of Sustainability Design



Verification:

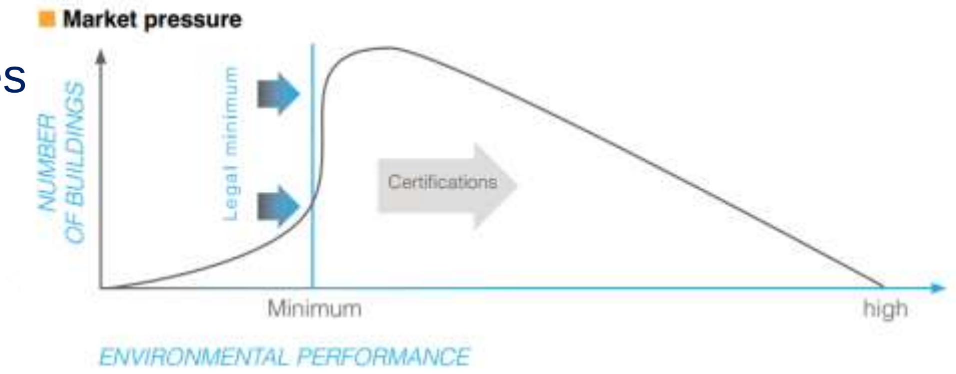
$\gamma_i S_d \leq R_d$

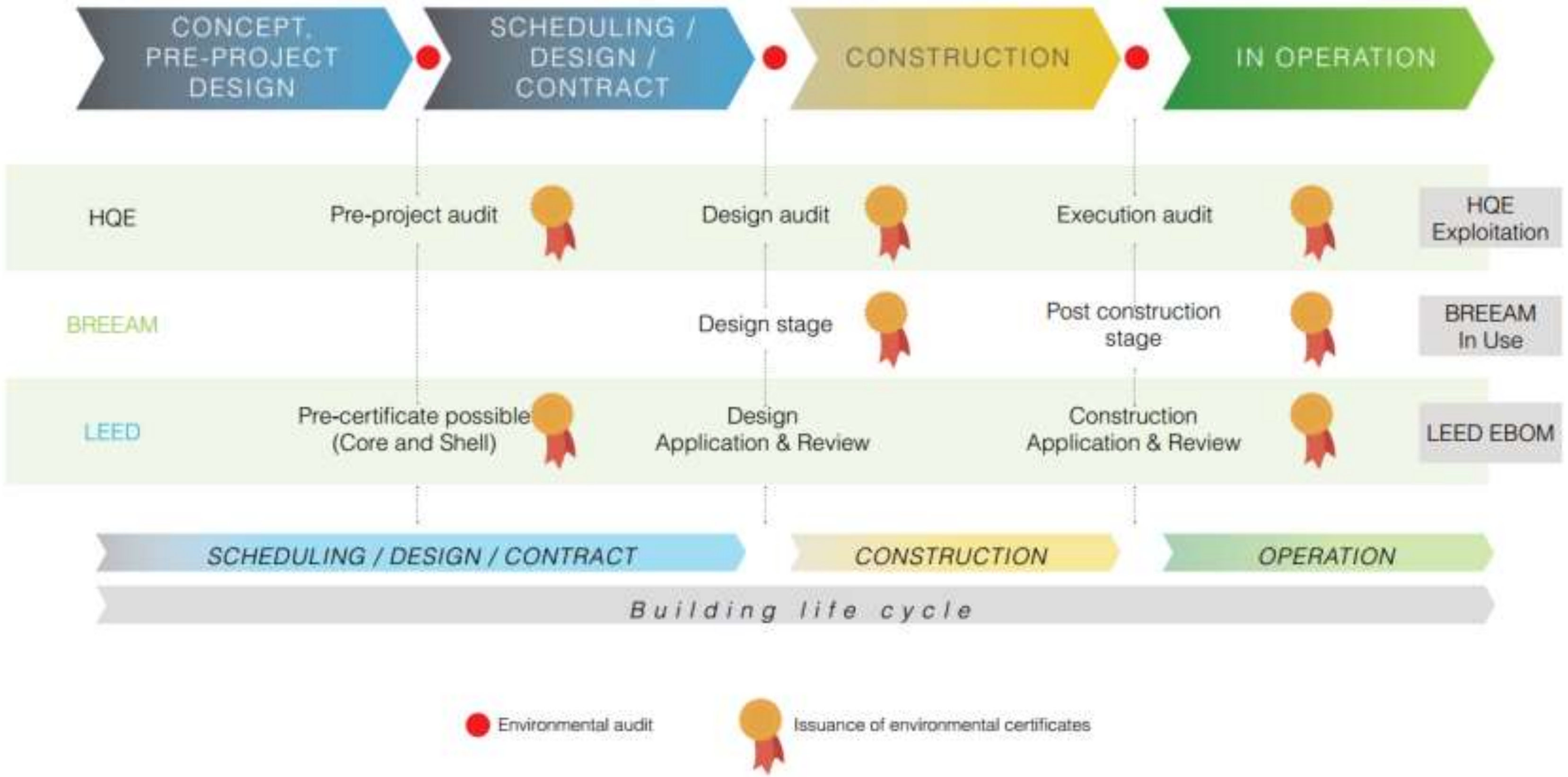
$\gamma_i \delta_d \leq \delta_a$

γ_i : Sustainability factor

Koji Sakai. Proposal for fib MC Revision. JCI-fib Joint Workshop, Tokyo, 1 September 2016

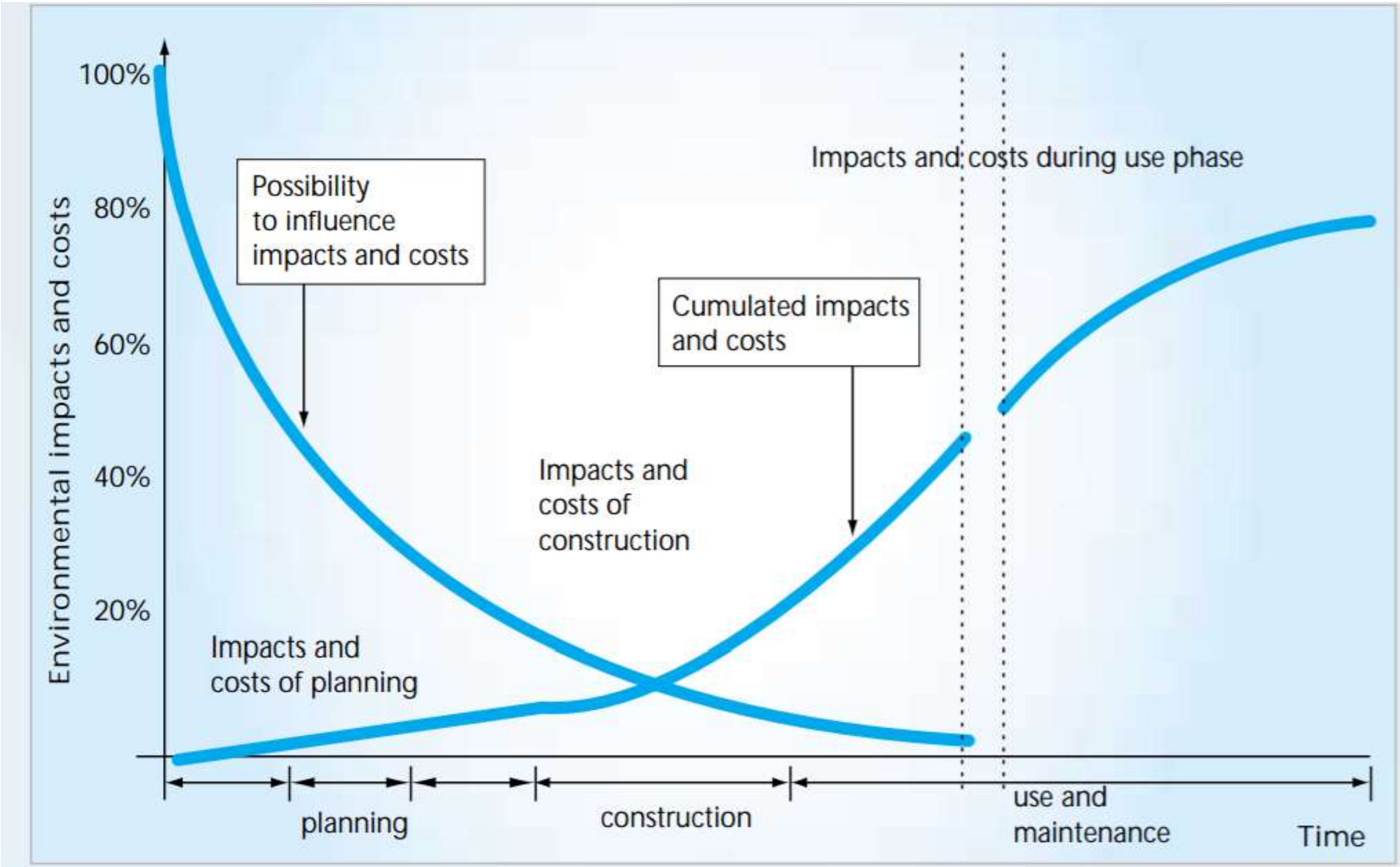
Certificados ambientais para construções





Cúpula do Panteón de Roma. 27 a.C.-125 d.C. (Agrippa)

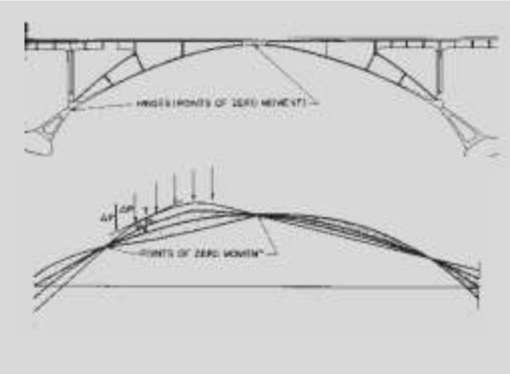
Influência da decisão de projeto no ciclo de vida e custo, tendo em vista edificações da Europa e América do Norte

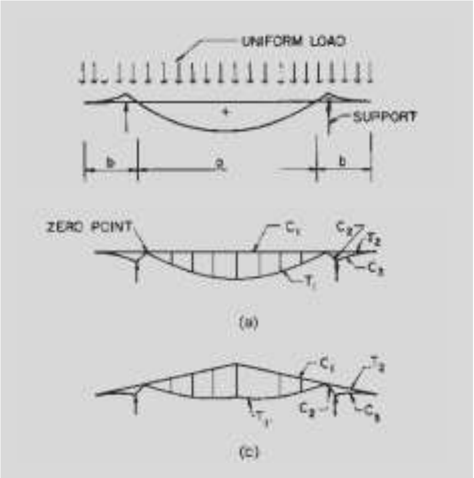


Source: Kohler, N. et al "Life-cycle analysis of the built environment". Sustainable building construction

Introduction

Robert Maillart (1872-1940)





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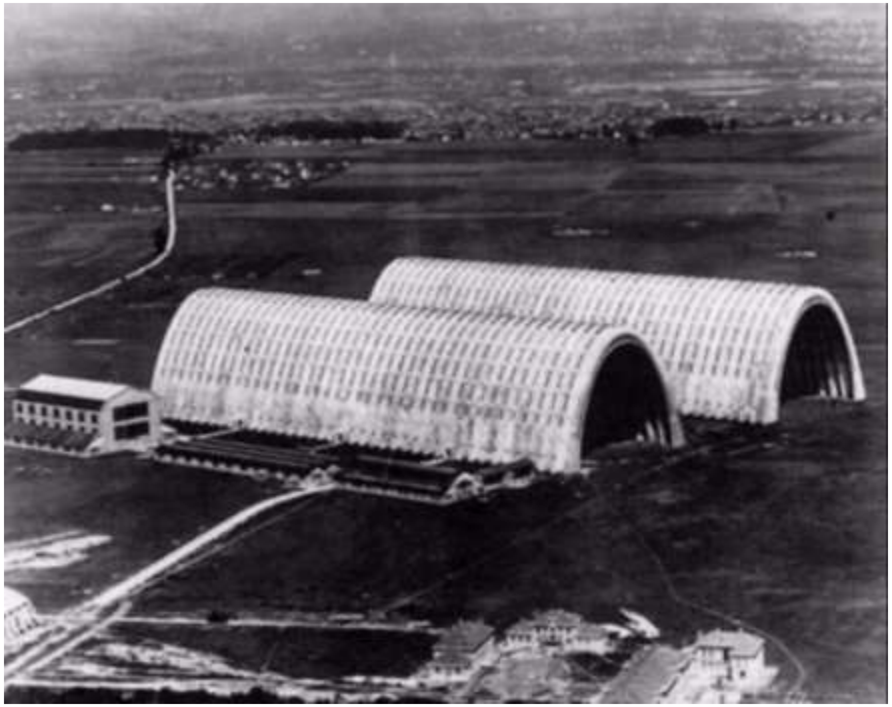
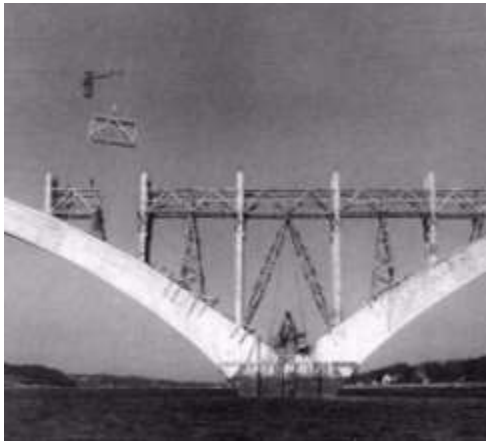
Introduction

Eugène Freyssinet (1879-1962)





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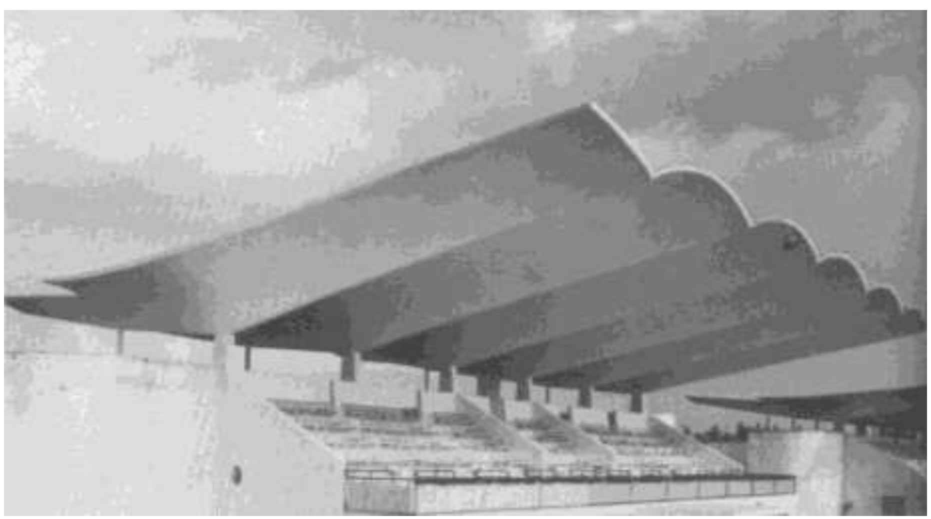
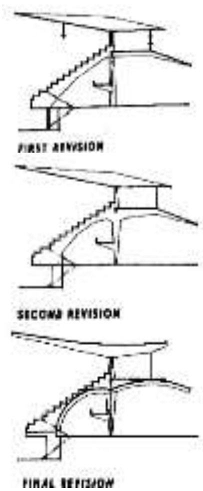
Introduction

Eduardo Torroja (1899-1961)

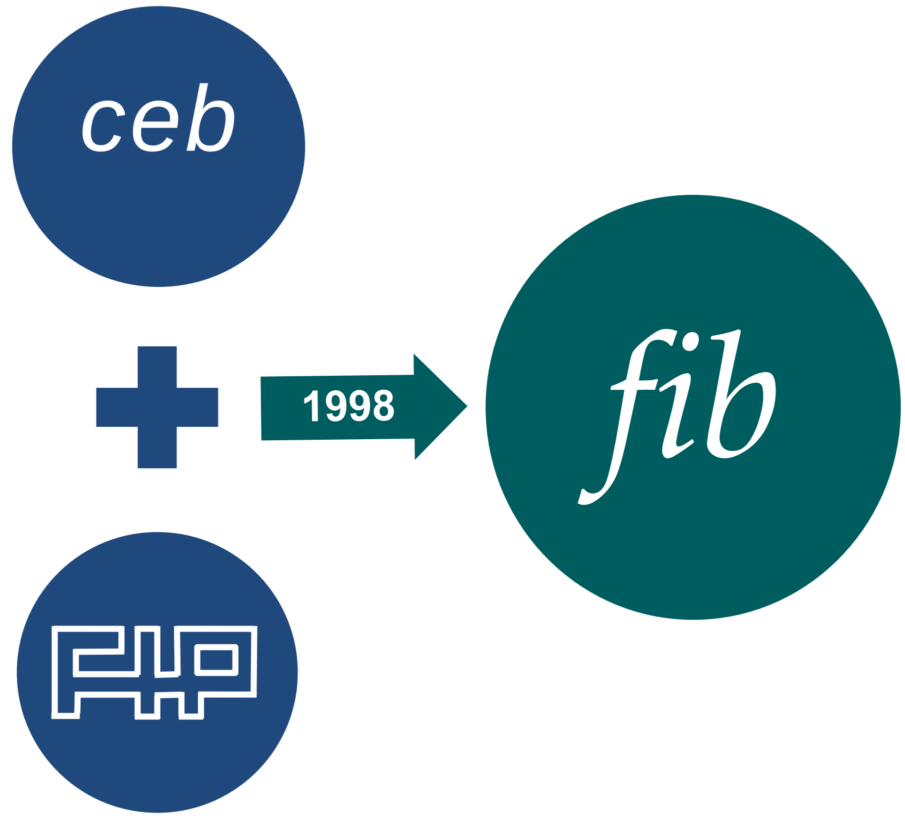




Criação da *fib*

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

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



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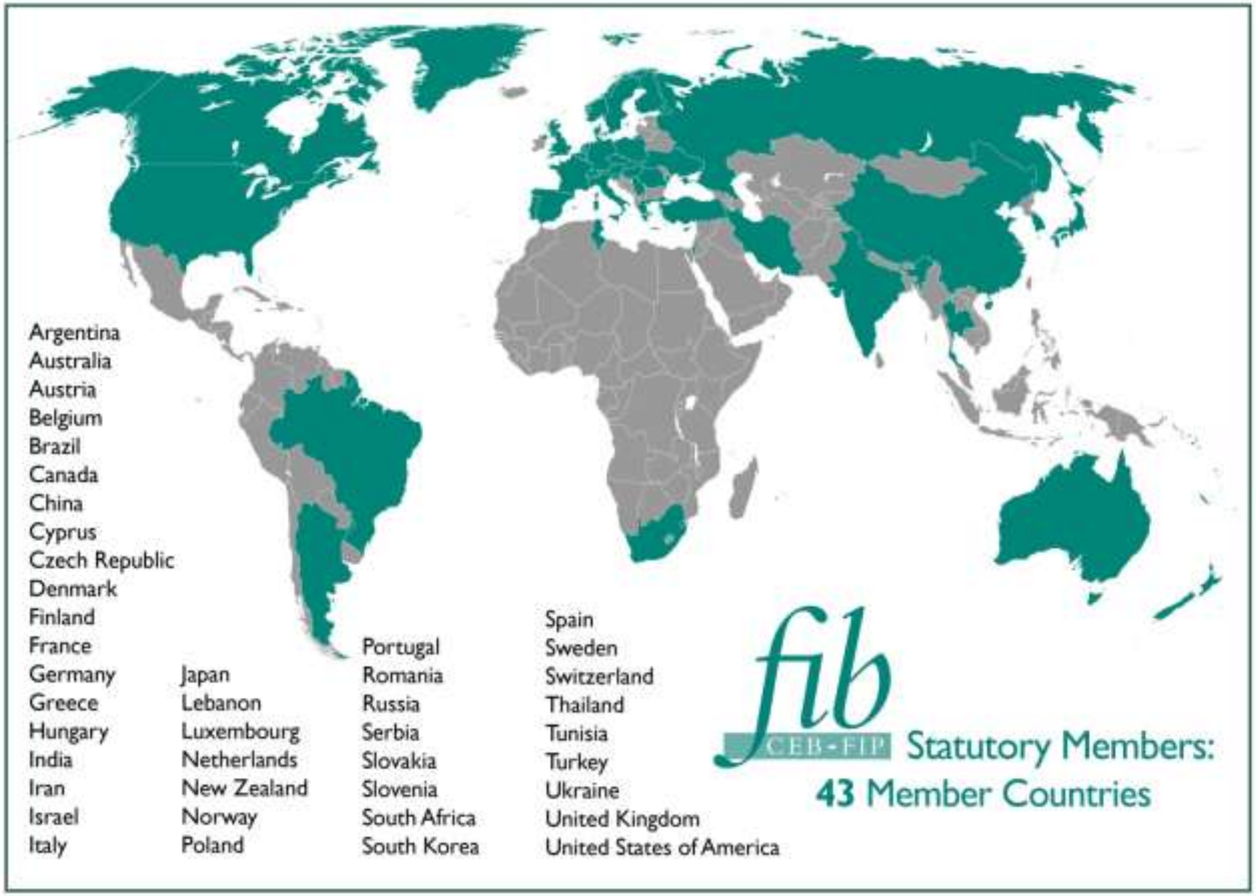
Missão e Objetivos da *fib*

“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*

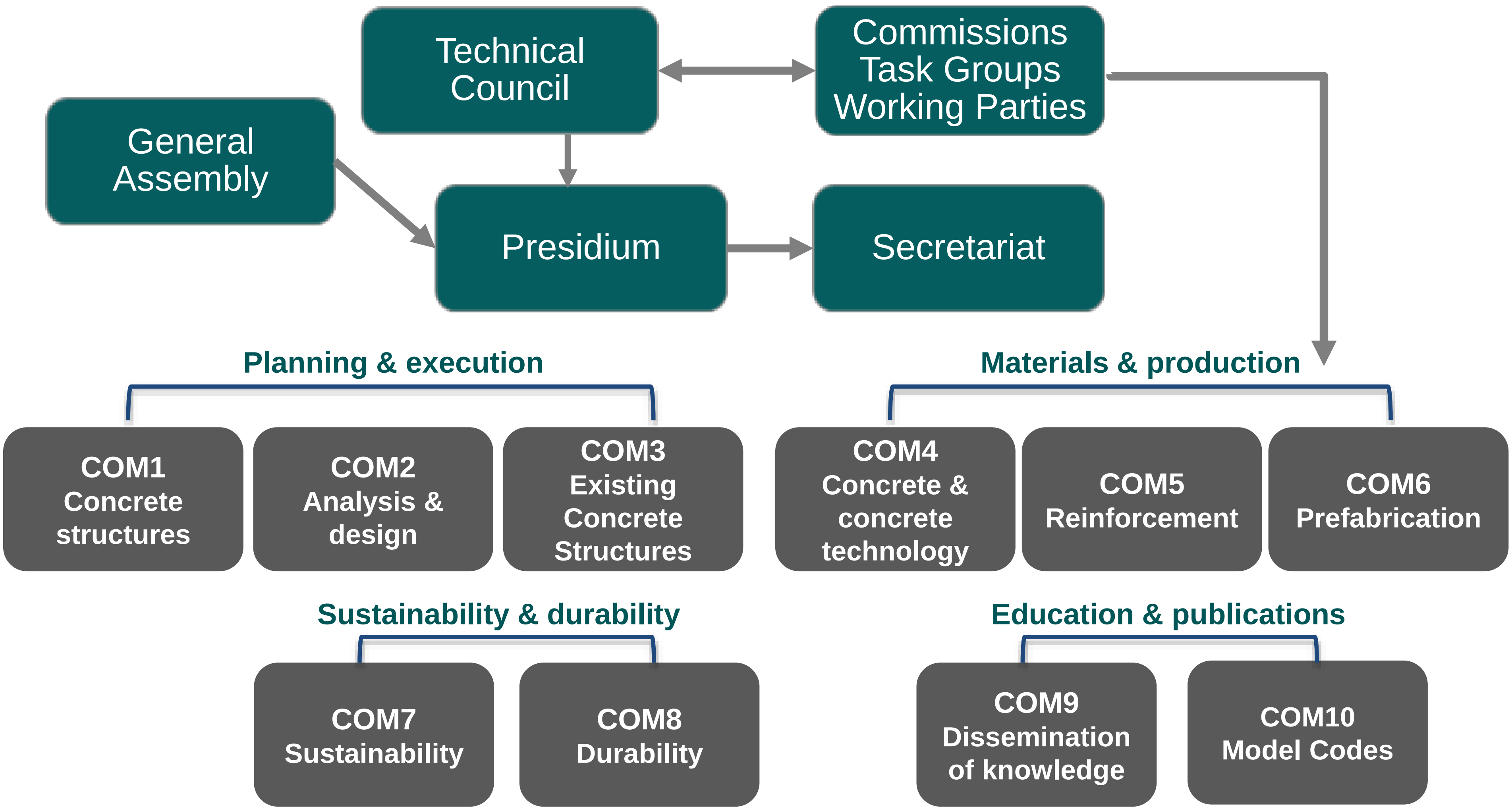


Grupo Nacional Brasileiro, formado por duas associações:

- **ABCIC**
- **ABECE**

fib

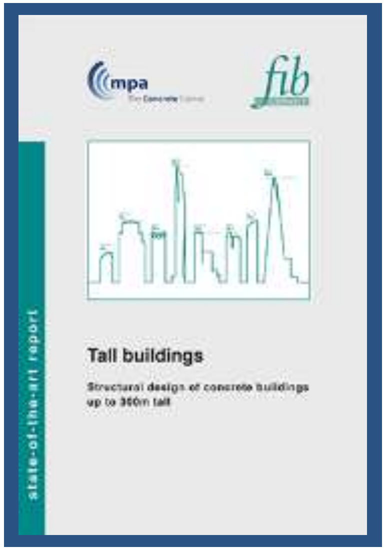
Estrutura Organizacional



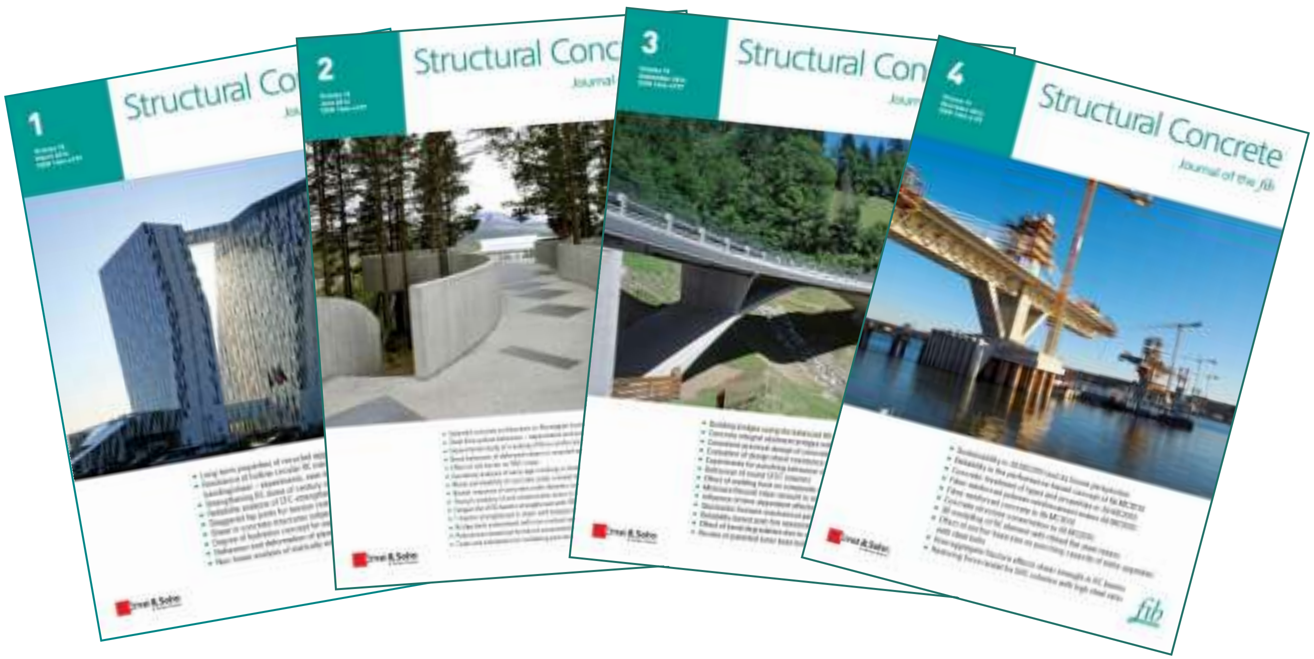
fib

Resultado das comissões e grupo de trabalho são publiacados nos boletins fib

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

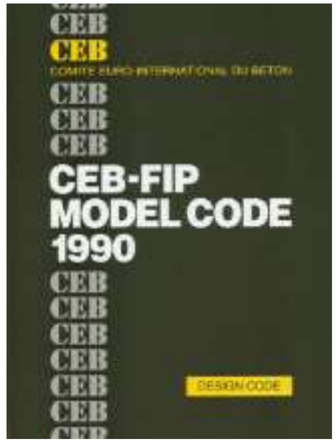


Impact factor 2015: 1.023

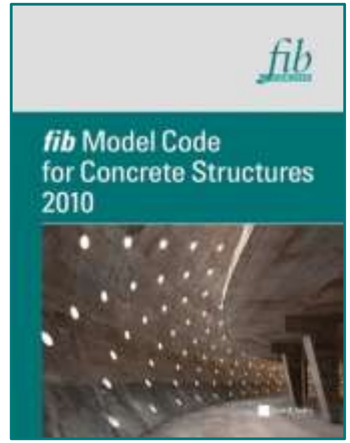


Evolução do Código Modelo

Model Code 1978

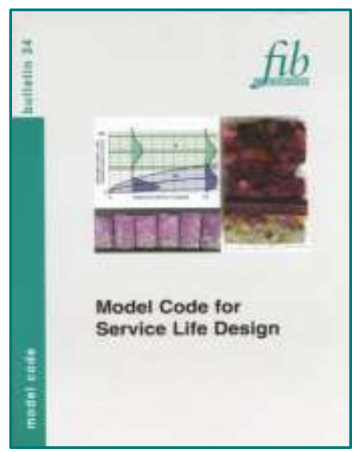


Model Code 1990



Model Code 2010

CEB Bull. 165 Seismic Design



fib Bull. 34 Service Life Design

fib

Estrutura Organizacional

Planning & execution

- COM1 Concrete structures
- COM2 Analysis & design
- COM3 Existing Concrete Structures

Materials & production

- COM4 Concrete & concrete technology
- COM5 Reinforcement
- COM6 Prefabrication

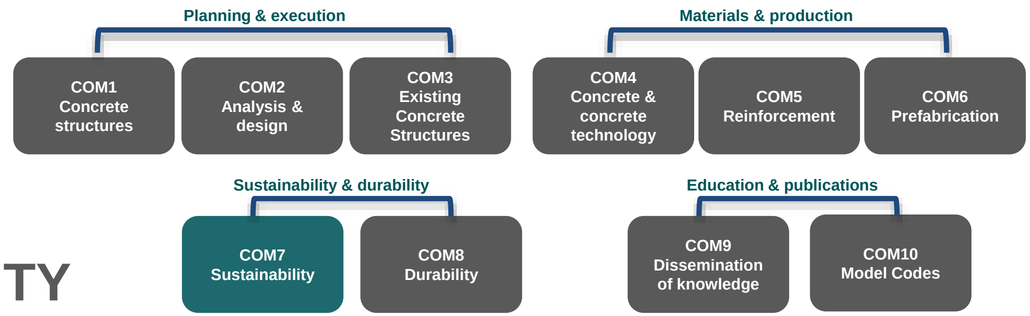
Sustainability & durability

- COM7 Sustainability
- COM8 Durability

Education & publications

- COM9 Dissemination of knowledge
- COM10 Model Codes

Estrutura em Comitês



COMMISSION 7 SUSTAINABILITY

Chair: Petr Hajek
Deputy Chair: Takafumi Noguchi

Task Group	Name	Chair
T7.1	Sustainable concrete-general framework	Hajek
T7.2	Applications of environmental design to concrete structures	Kawai
T7.3	Concrete made with recycled materials – life cycle perspective	Noguchi
T7.4	Sustainable civil structures	Kohoutkova
T7.5	Environmental product declarations (EPD) and equivalent performance for concrete	Mathiesen
T7.6	Resilient structures	Asprone
T7.7	Sustainable concrete masonry components	Parisi

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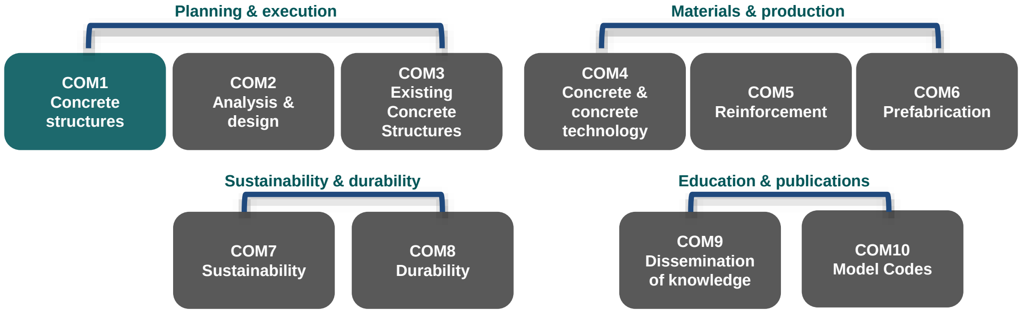
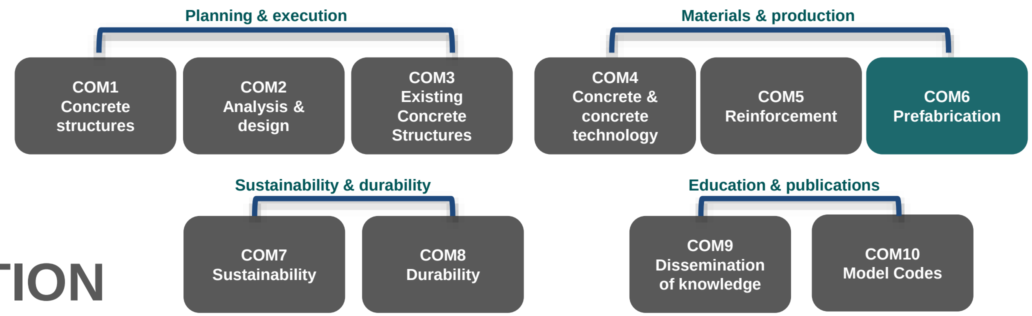
Estrutura em Comitês



COMMISSION 1 STRUCTURES

Chair: Moussard

Task Group	Name	Chair
T1.5	Structural sustainability	Kasuga

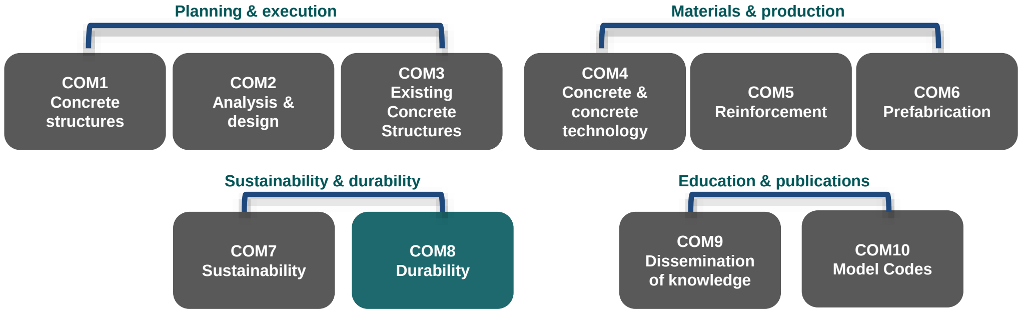


COMMISSION 6 PREFABRICATION

Chair: Maas

Task Group	Name	Chair
T6.3	Sustainability of structures with precast elements	Fernández-Ordonez

Estrutura em Comitês

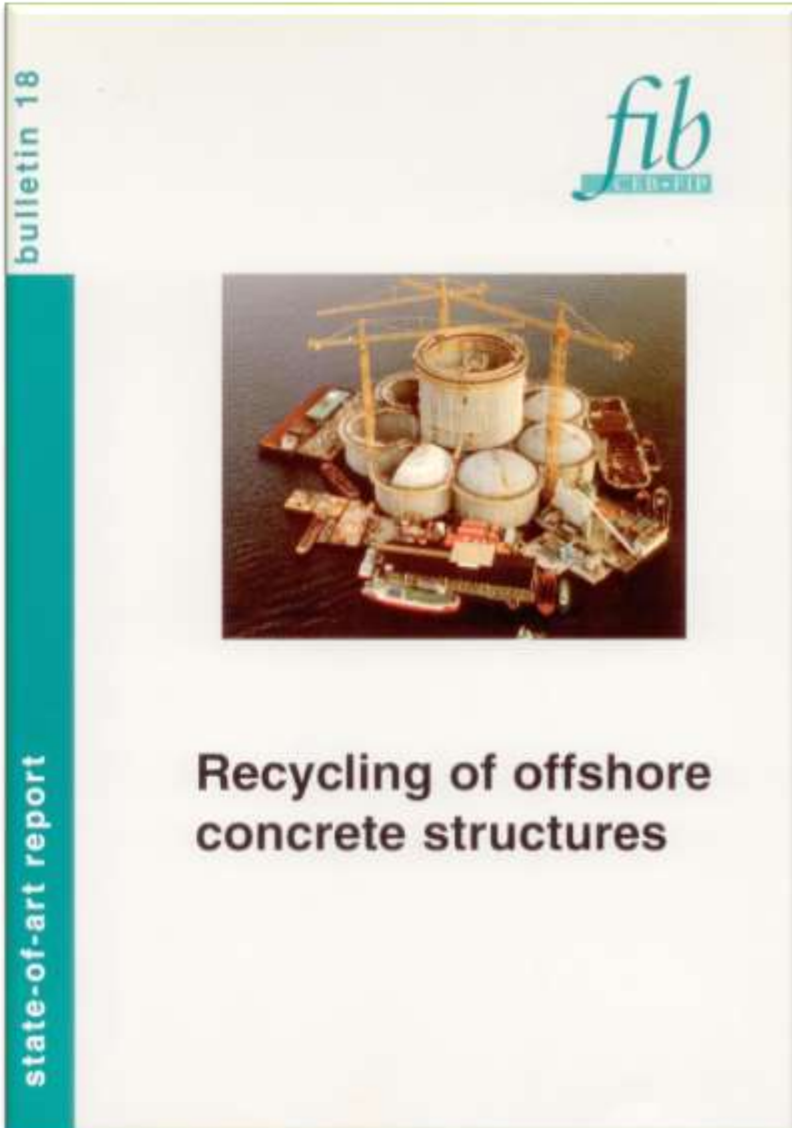


COMMISSION 8 DURABILITY

Chair: Pielstick

Task Group	Name	Chair
T8.3	Operational document to support Service Life Design.	Andrade
T8.4	Life cycle cost (LCC) - Design life and/or replacement cycle	Campos e Matos

Aspectos ambientais e Sustentabilidade



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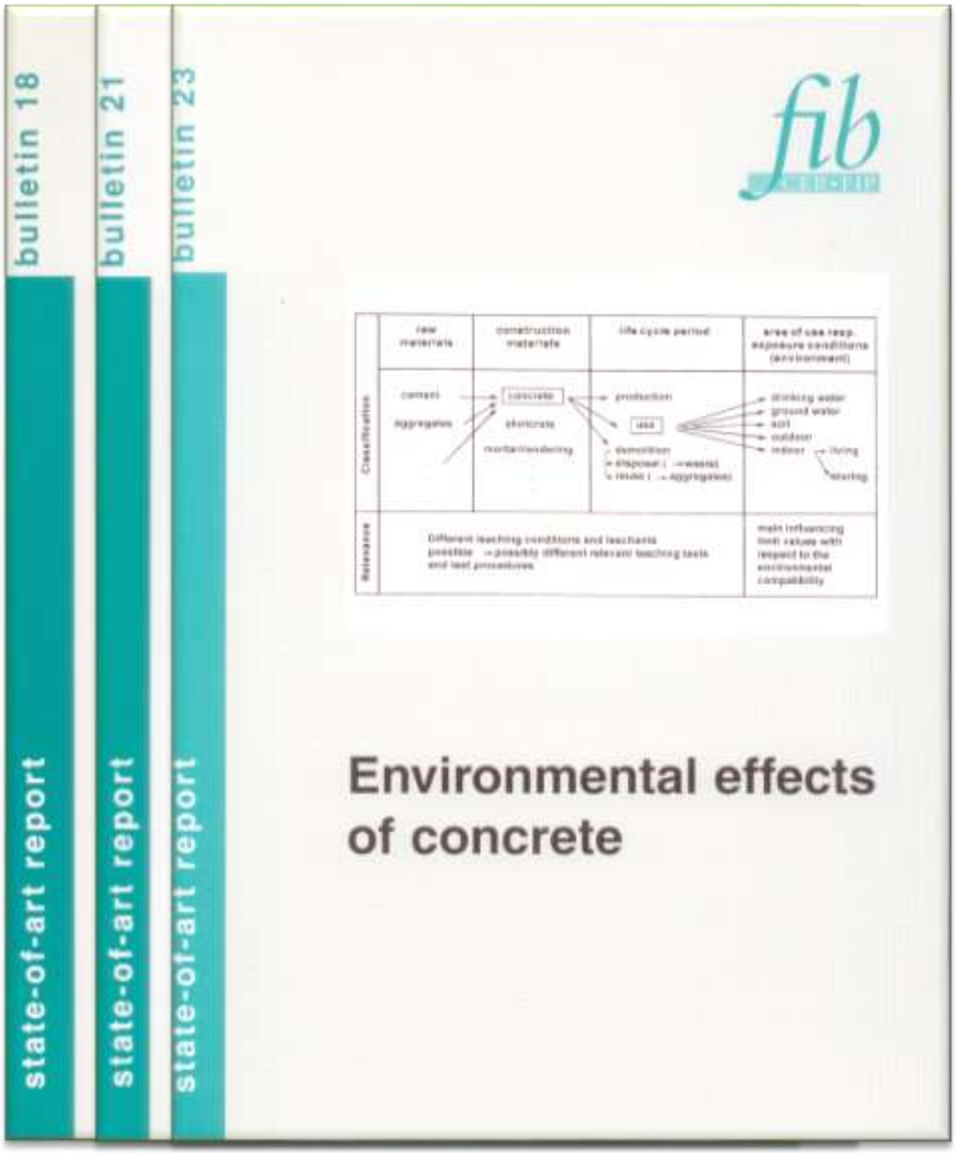
Aspectos ambientais e Sustentabilidade

Aspectos ambientais e Sustentabilidade



2 *fib*

Aspectos ambientais e Sustentabilidade

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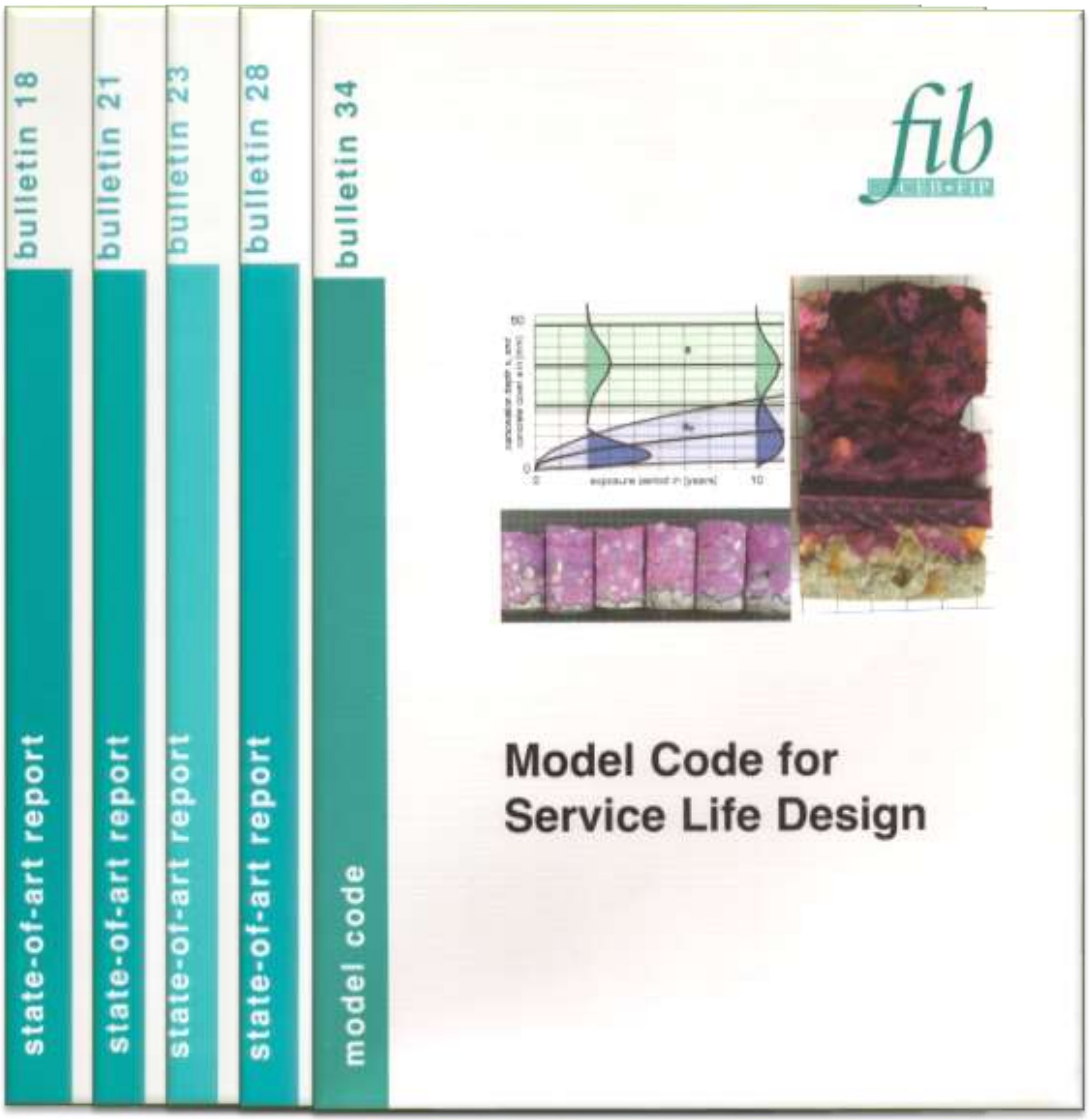
Aspectos ambientais e Sustentabilidade



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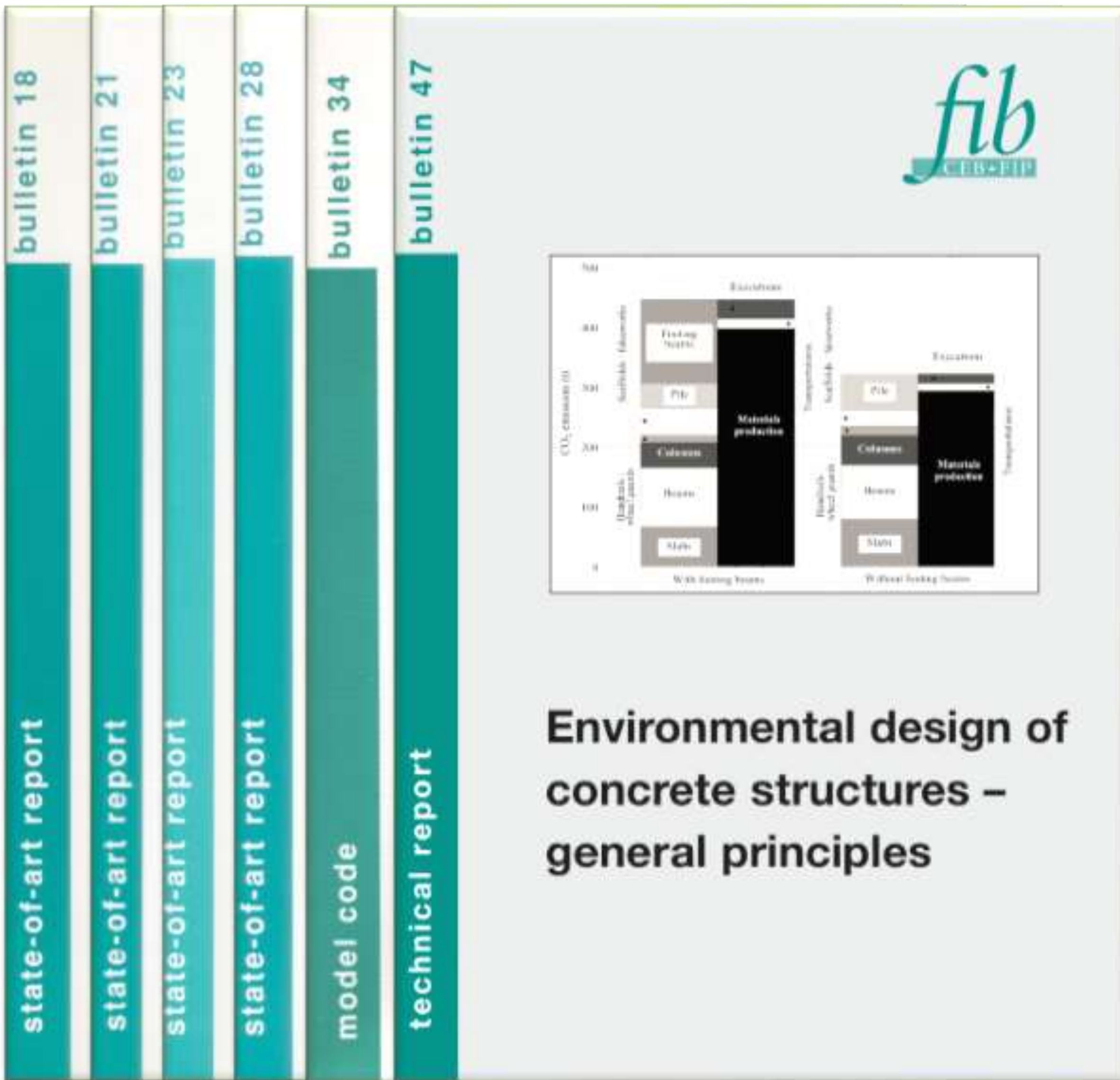
Aspectos ambientais e Sustentabilidade



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Aspectos ambientais e Sustentabilidade

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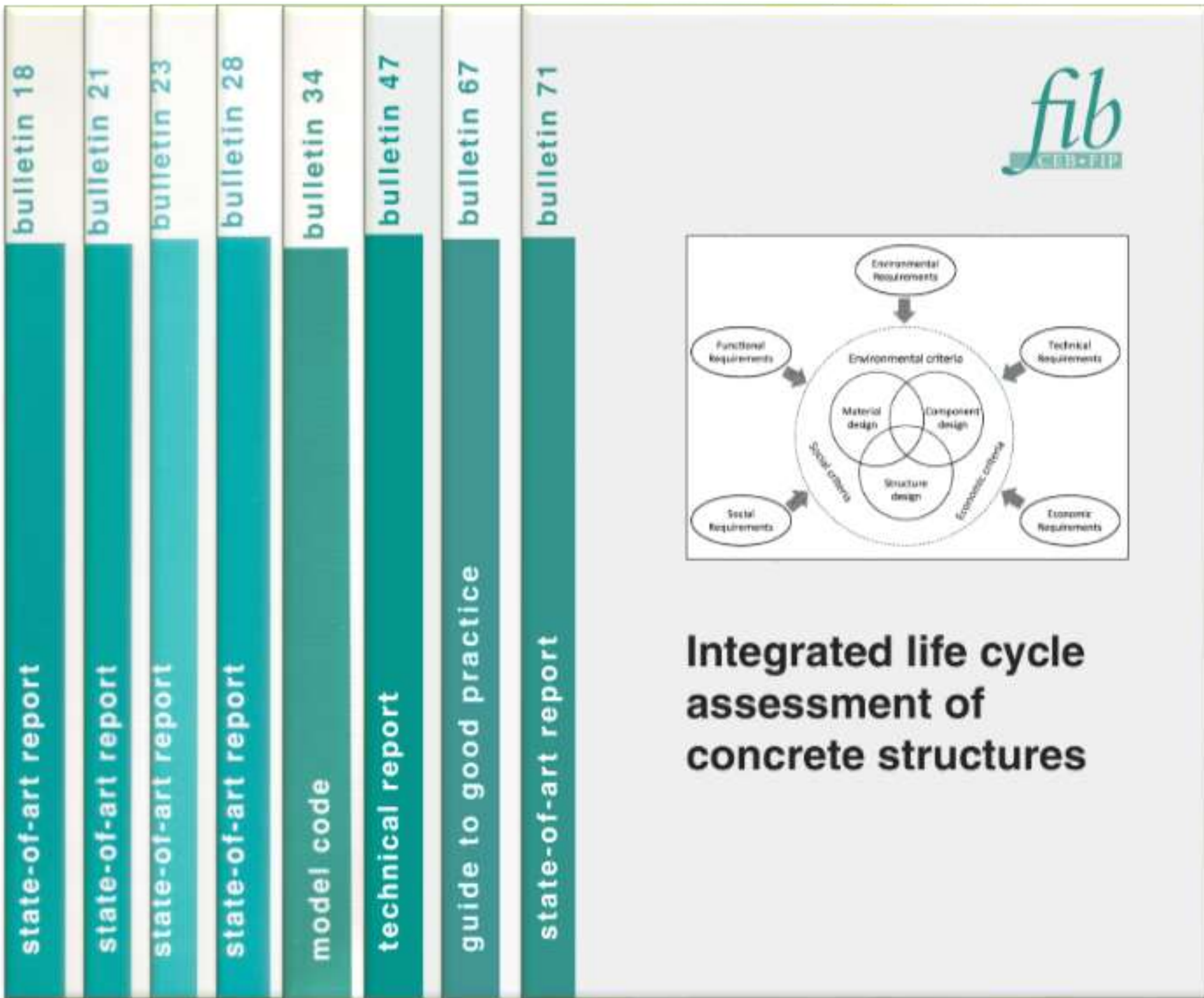
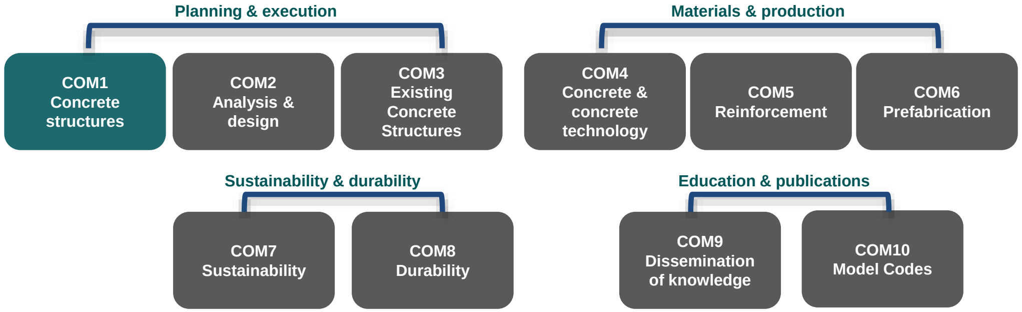
Aspectos ambientais e Sustentabilidade



Structural Sustainability / Conceptual Design

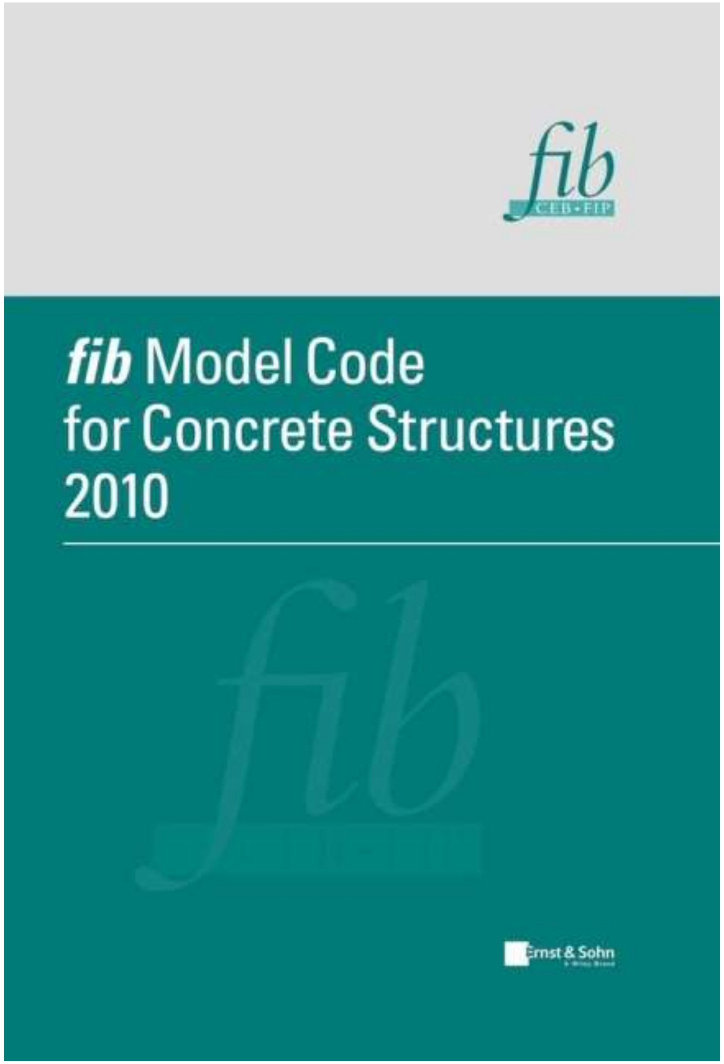
Estrutura em Comitês



COMMISSION 1 STRUCTURES

Chair: Moussard

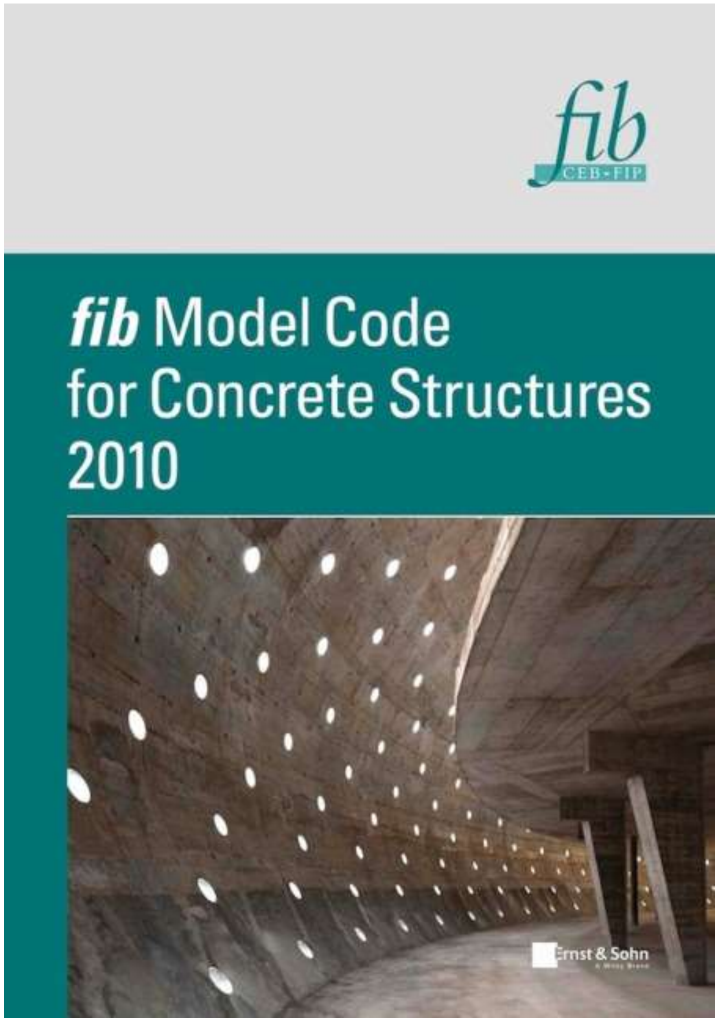
Task Group	Name	Chair
T1.5	Structural sustainability	Kasuga



Preface

Notations

PART I:	**PRINCIPLES**
PART II:	**DESIGN INPUT DATA**
PART III:	**DESIGN**
PART VI:	**CONSTRUCTION**
PART V:	**CONSERVATION AND DISMANTLEMENT**



Preface

Notations

PART I: **PRINCIPLES**

PART II: **DESIGN INPUT DATA**

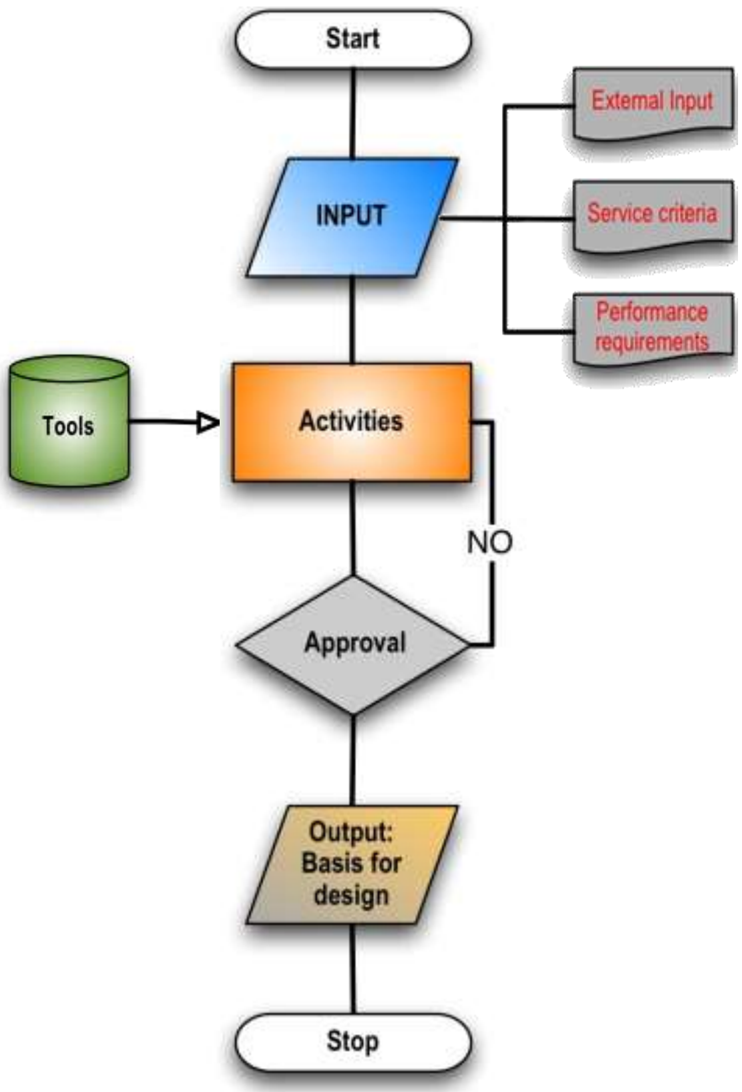
PART III: **DESIGN**

- 7. Design
- 7.1 **Conceptual design**
- 7.2 Structural analysis and dimensioning
- 7.3 Verification of structural safety (ULS) for predominantly static loading
- 7.4 Verification of structural safety (ULS) for non-static loading
- 7.5 Verification of structural safety (ULS) for extreme thermal conditions
- 7.6 Verification of serviceability (SLS) of RC and PC structures
- 7.7 Verification of safety and serviceability of FRC structures
- 7.8 Verifications of limit states associated to durability
- 7.8.8 Alkali-aggregate reactions
- 7.9 Verification of robustness
- 7.10 Verification of sustainability
- 7.11 Verifications
- 7.12 Verifications assisted by testing
- 7.13 Detailing

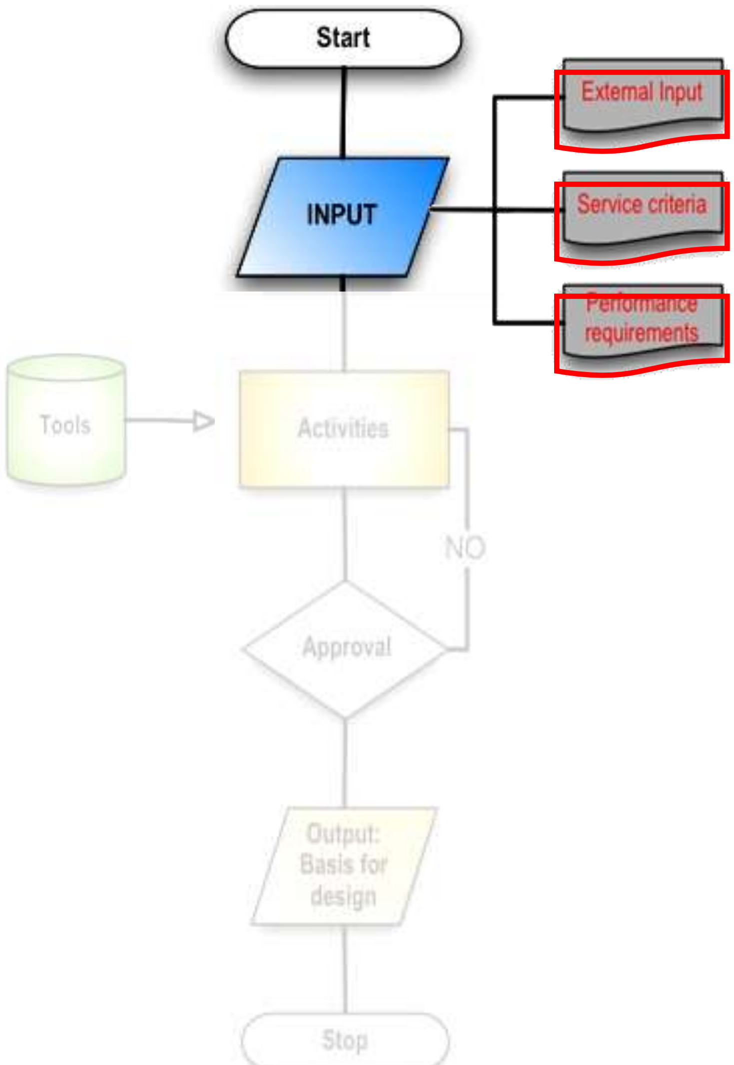
PART VI: **CONSTRUCTION**

PART V: **CONSERVATION AND DISMANTLEMENT**

CONCEPTUAL DESIGN: GENERAL PROCESS



CONCEPTUAL DESIGN: GENERAL PROCESS



External or technical Input

- Drawings, sketches (from architects, from owner)
- General layout, plans, of site, topography
- Technical data about the site (soil conditions, geology)
- Environmental data (weather, wind, floods, earthquake, etc.)
- Accessibility and transport facilities
- Local construction rules
- Pictures of the site

At disposal or to be asked to the owner or the architect or to authorities, or to be organised or set up by the designer

Service criteria

- Use of structure (efficiency, comfort and safety)
- Operational requirements (efficiency, economy)
- Maintenance requirements (efficiency, economy)
- Special requirements (upgrading, replacement, etc.)

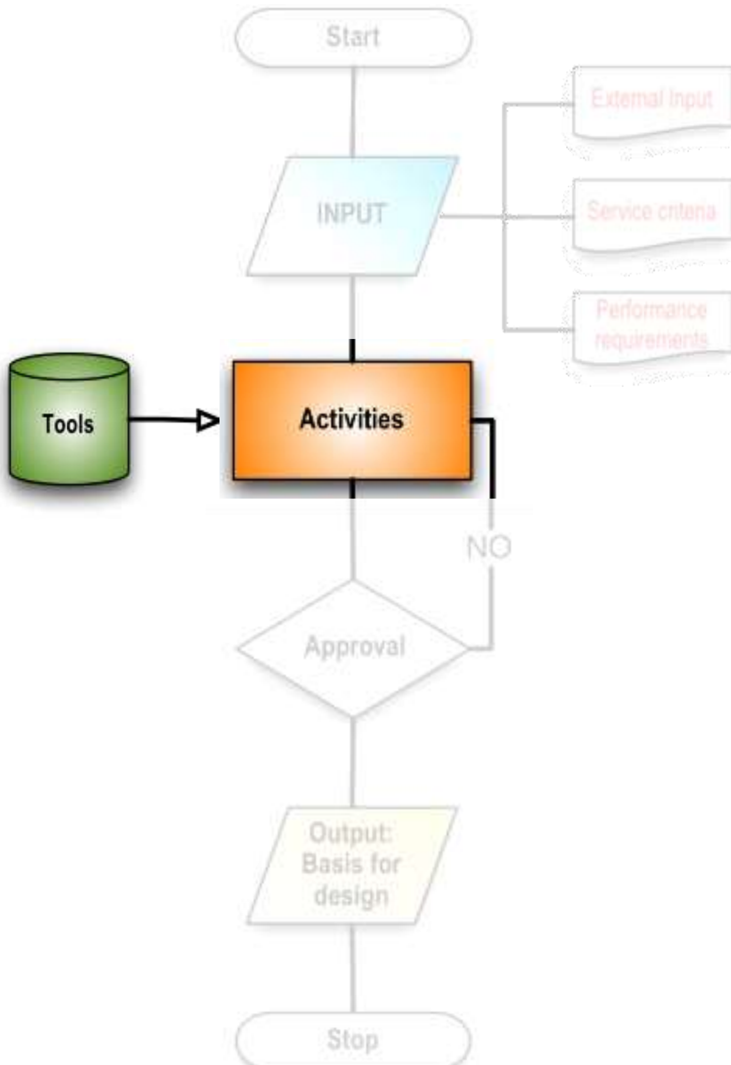
To be discussed and established together with the owner or the architect and must be approved by everybody

Performance requirements

- Service life (temporary, replaceable, evolutive, long term)
- Solidity (for determined design values - risk evaluation)
- Structural efficiency
- Durability
- Aesthetics
- Integration in its surroundings
- Economy (budget)
- Construction method
- **Sustainability**
- Replacement
- Demolition
- Recycling

To be established, proposed and explained by the designer and must be approved by the owner

CONCEPTUAL DESIGN: GENERAL PROCESS



Activities

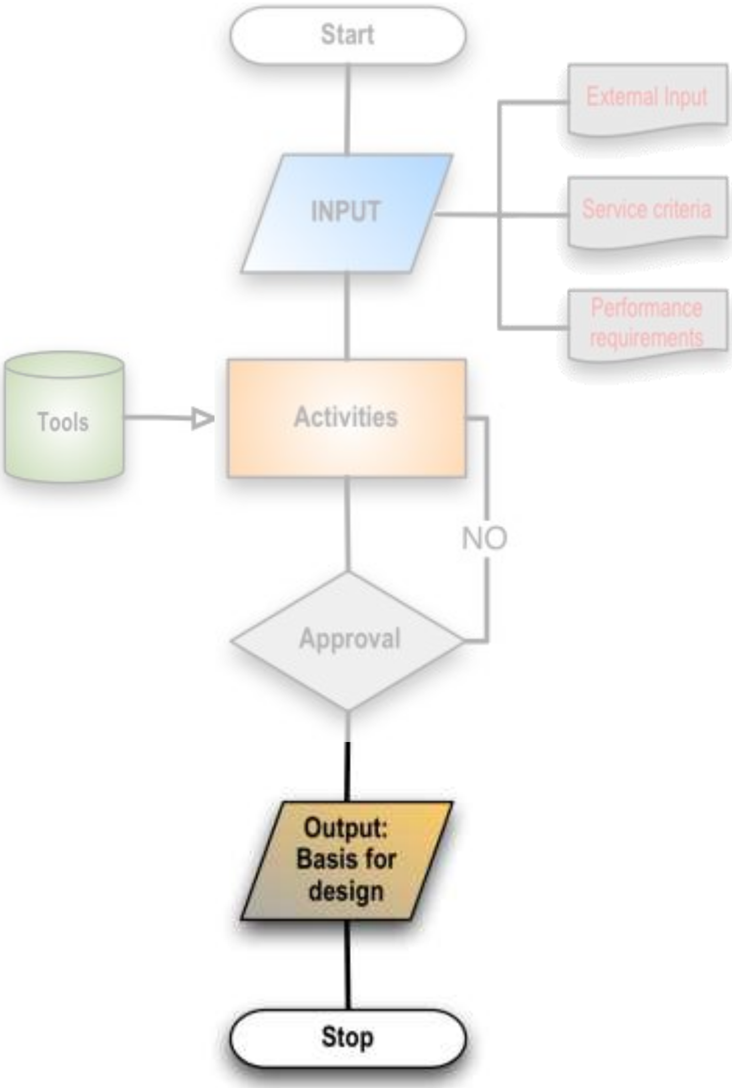
- Constraints Analysis and classification
- Environmental analysis (including local politics and local traditions)
- General conception
- Choice of materials (considering economy and energy consumption for production and elimination)
- Structural concept (structural logic, dimensions,)
- Integration and aesthetics (legibility, simplicity, proportions, equilibrium, shapes, detail philosophy)
- Construction method (sequences)
- Rough cost estimate
- Alternatives comparisons
- Successive presentation, explanation and discussions with the owner (architect)
- After acceptance by the owner - preparation of the

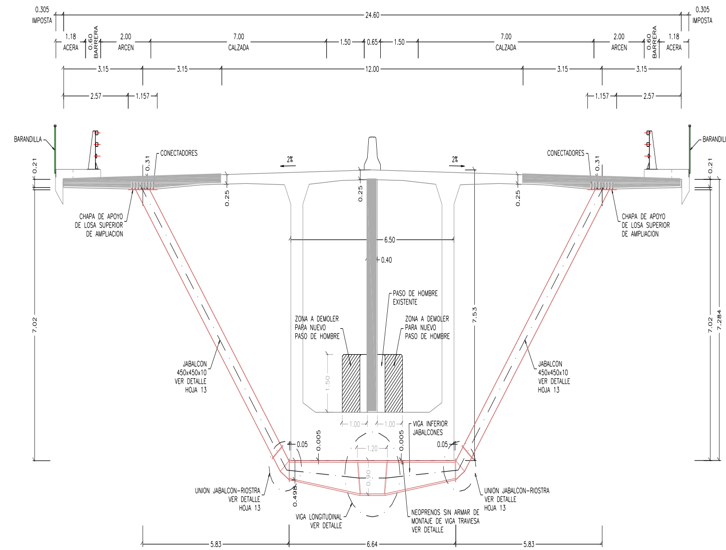
Tools

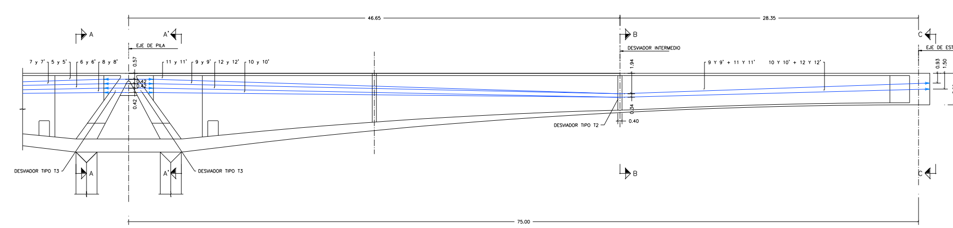
- Experience, background, feedback, database
- Feeling, sensibility,
- Creativity, imagination,
- Capacity of simultaneously analysing and integrating all criteria and constraints with their respective weights
- Quick Pre-design methods
- Design by sketching (from rough freehand sketches to accurate drawings)
- Visualization tools

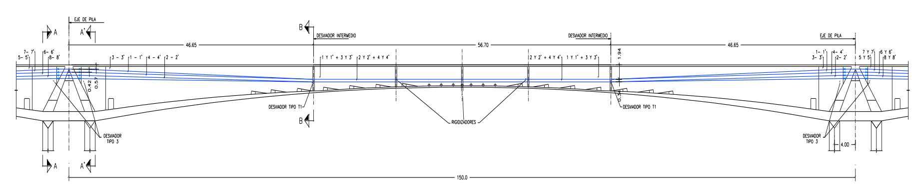
- Visualization tools

CONCEPTUAL DESIGN: GENERAL PROCESS



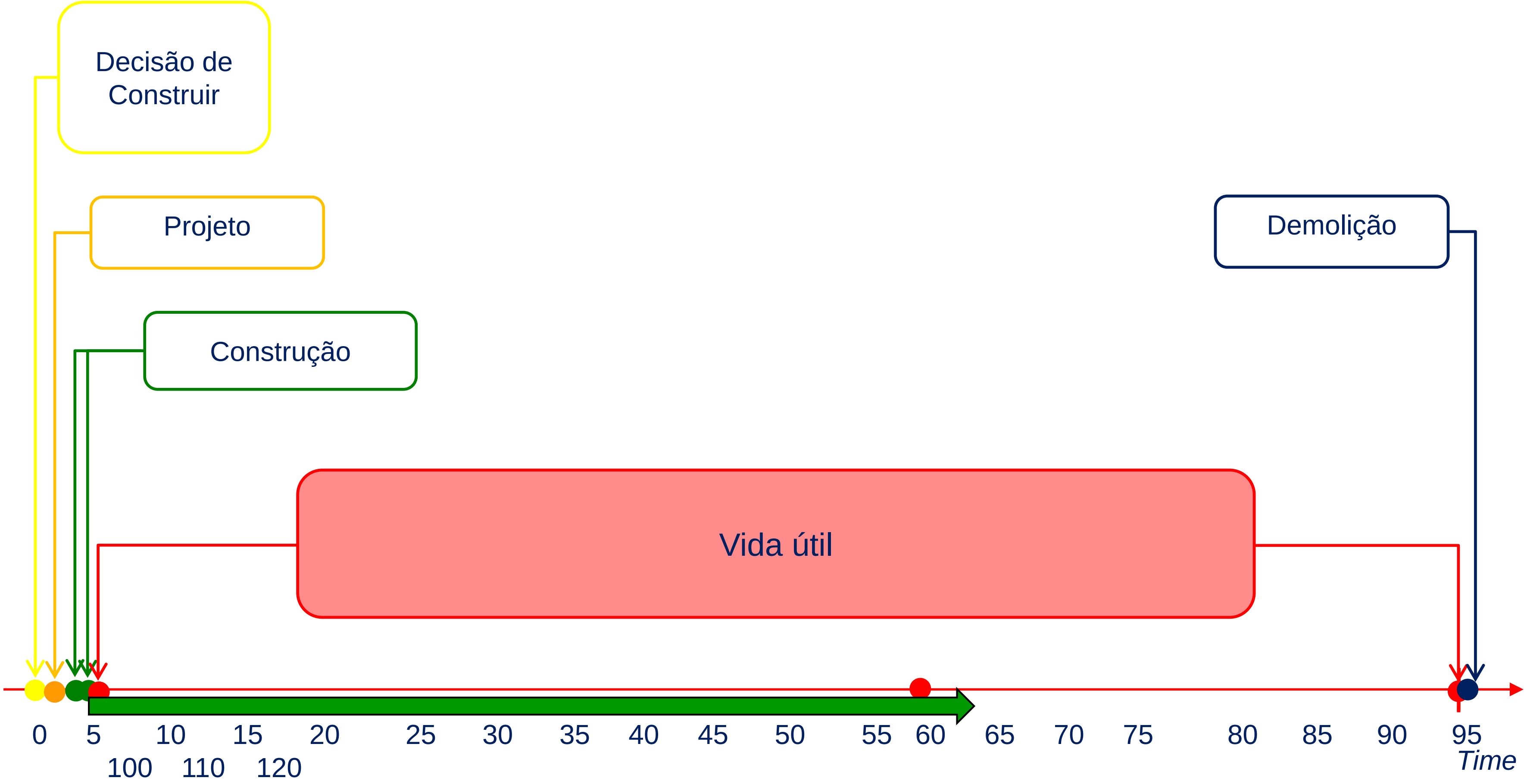






Structural Sustainability / Conceptual Design

Ponte Los Santos

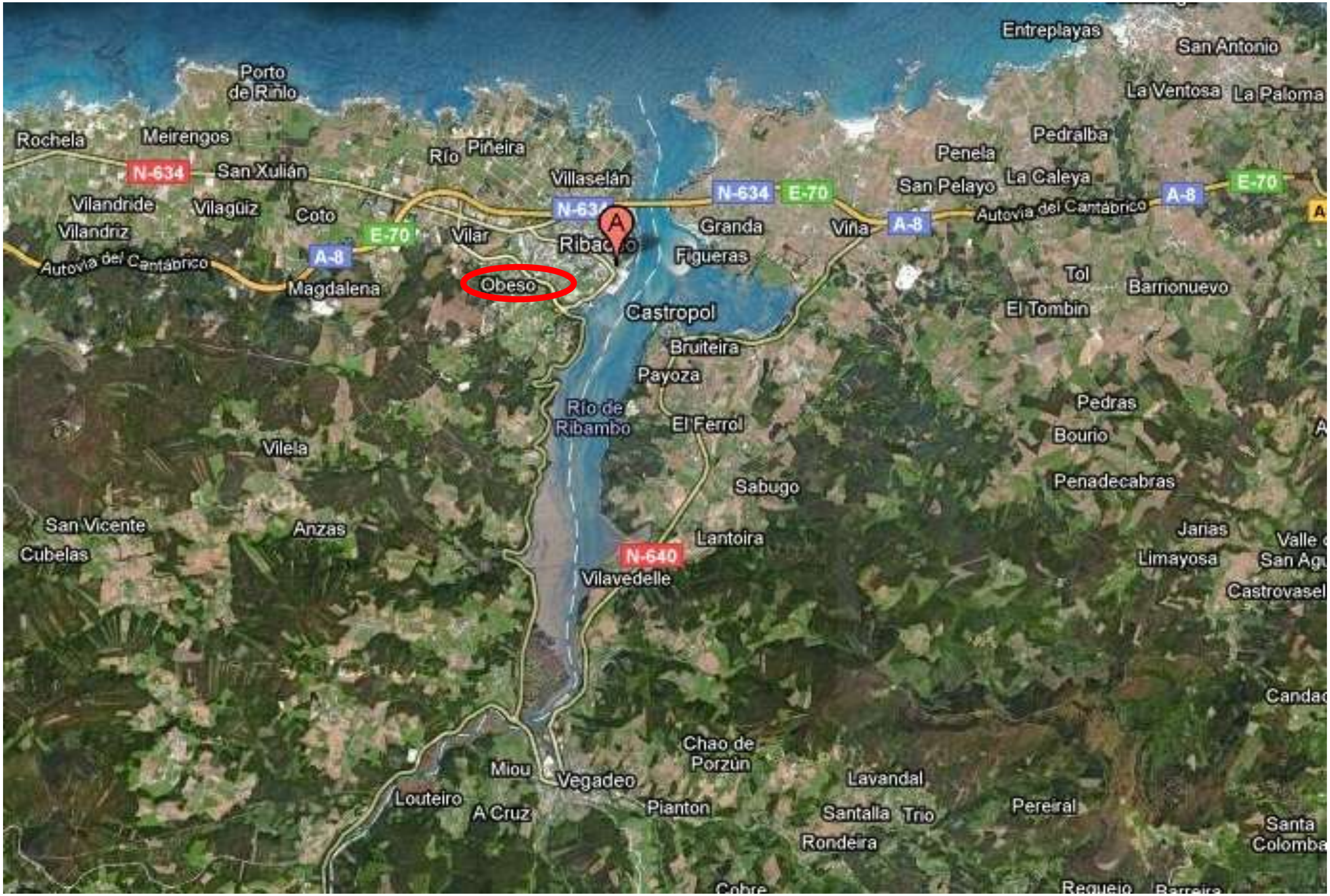


Structural Sustainability / Conceptual Design

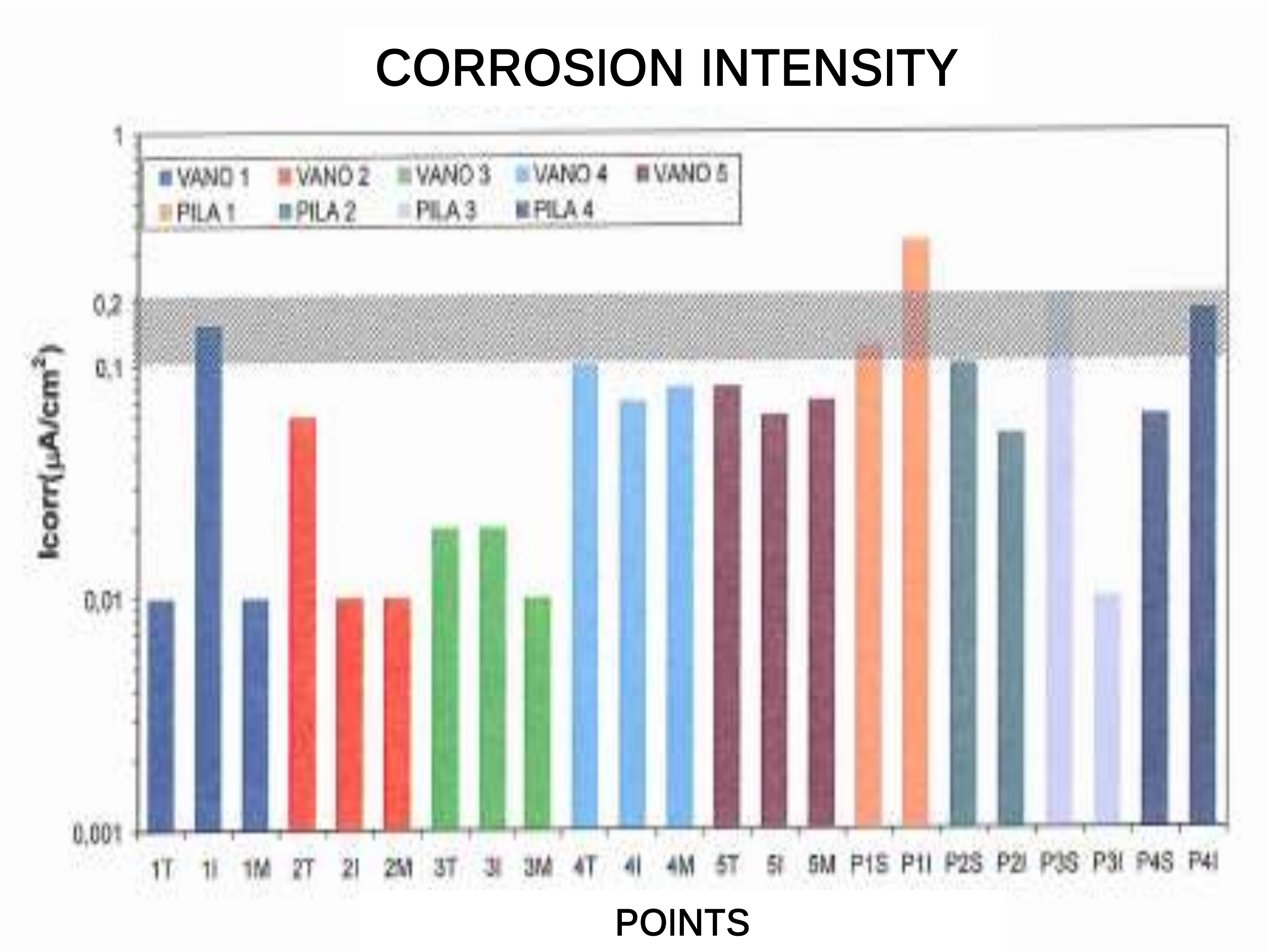
Ponte Los Santos

Structural Sustainability / Conceptual Design

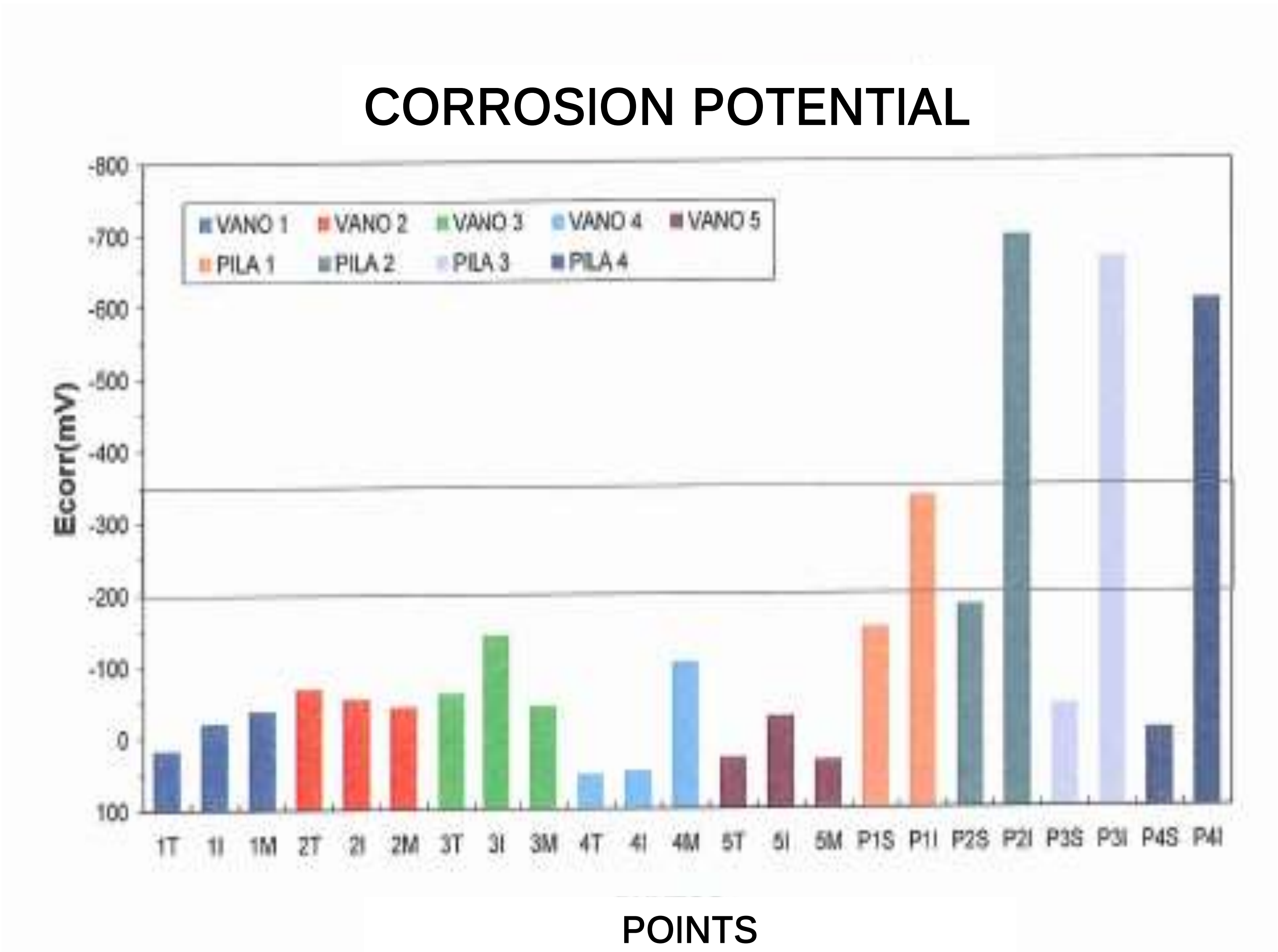
Ponte Los Santos



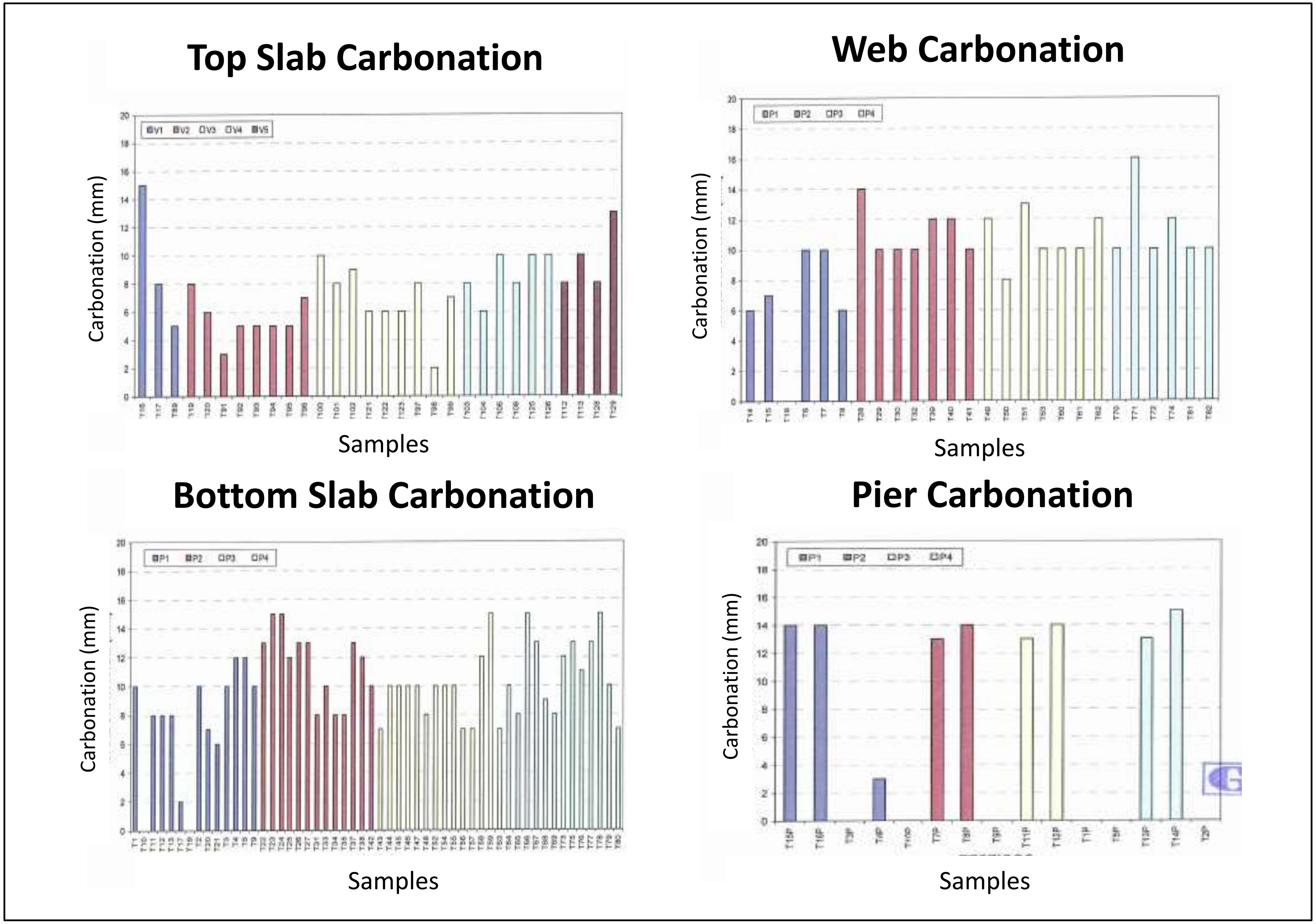
Ponte Los Santos



Ponte Los Santos

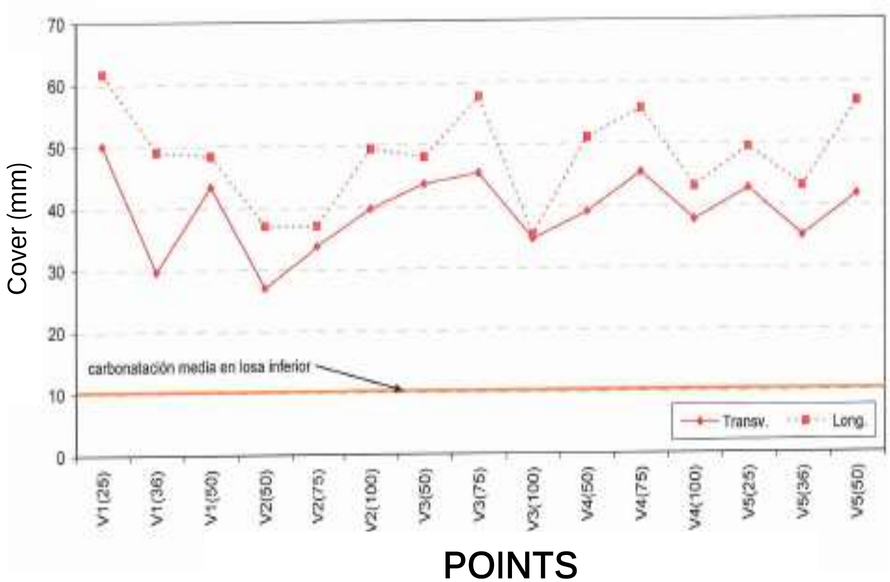


Ponte Los Santos

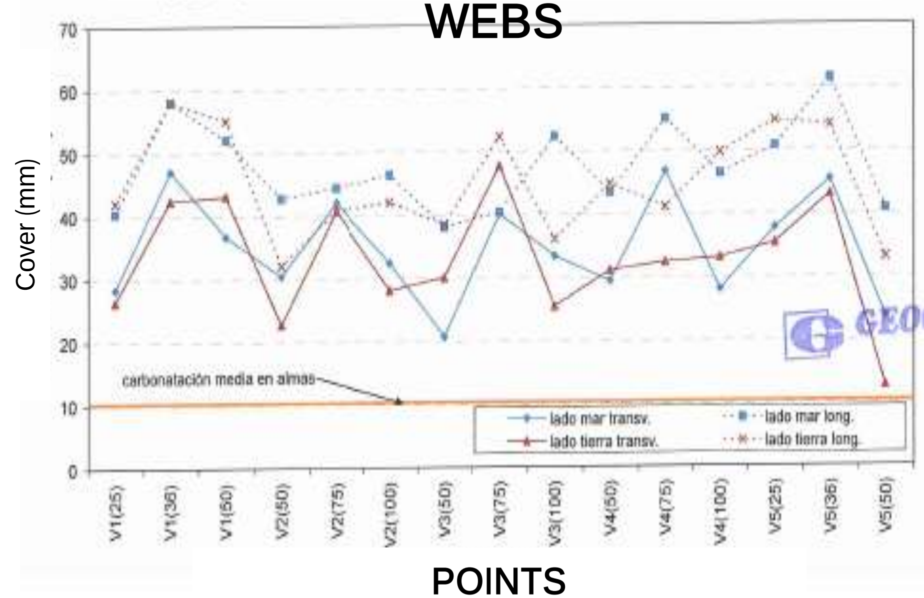


Ponte Los Santos

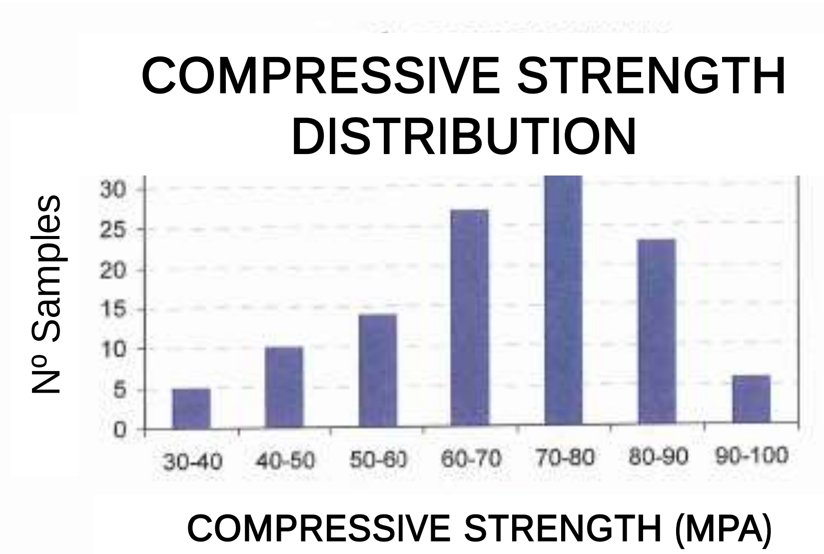
CONCRETE COVER IN THE BOTTOM SLAB

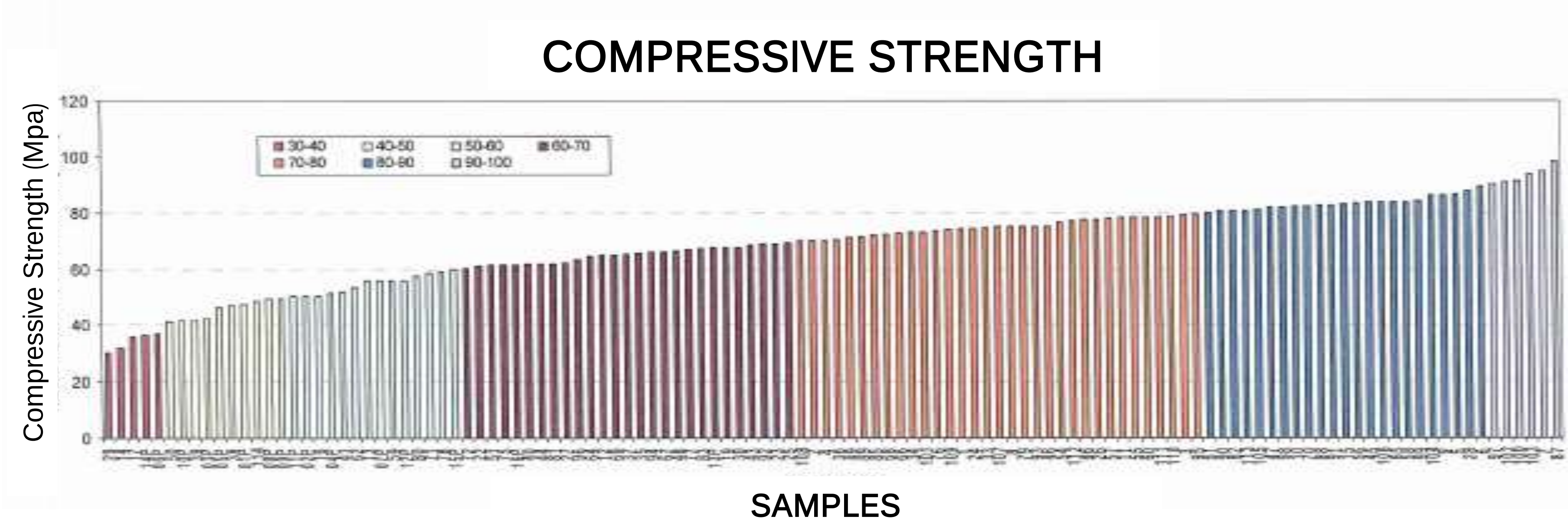


CONCRETE COVER IN THE WEBS



Ponte Los Santos





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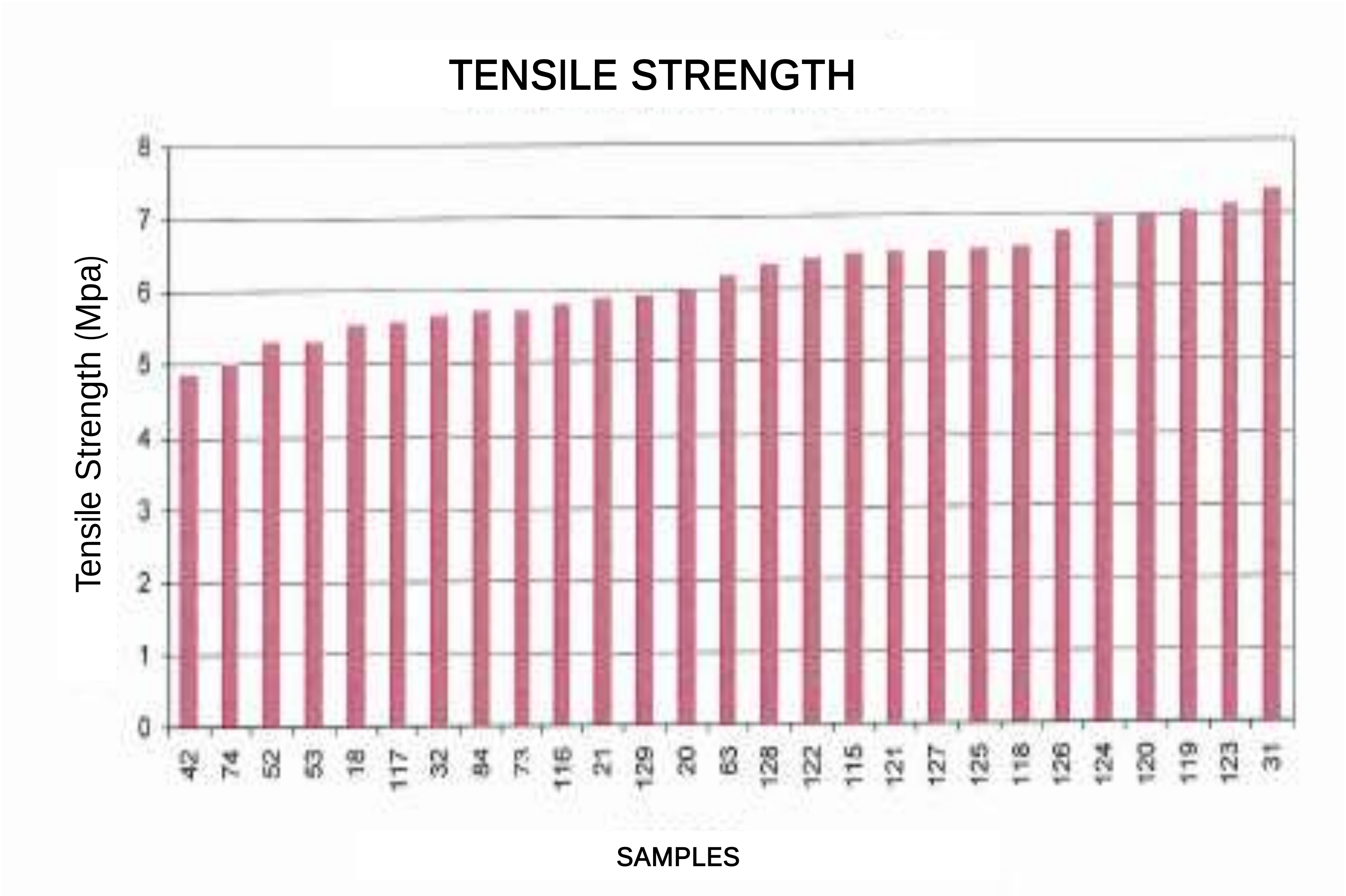
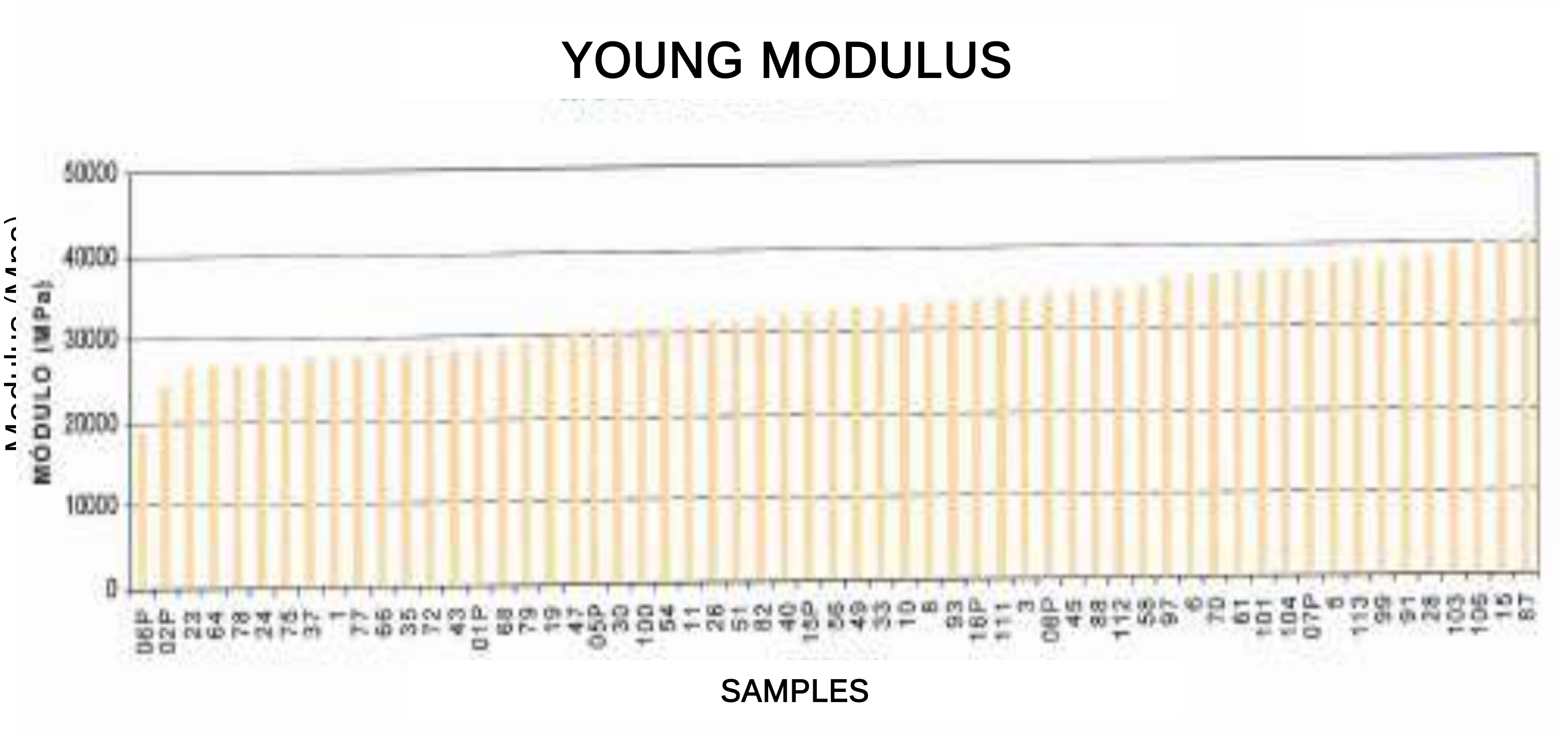


Structural Sustainability / Conceptual Design

Ponte Los Santos



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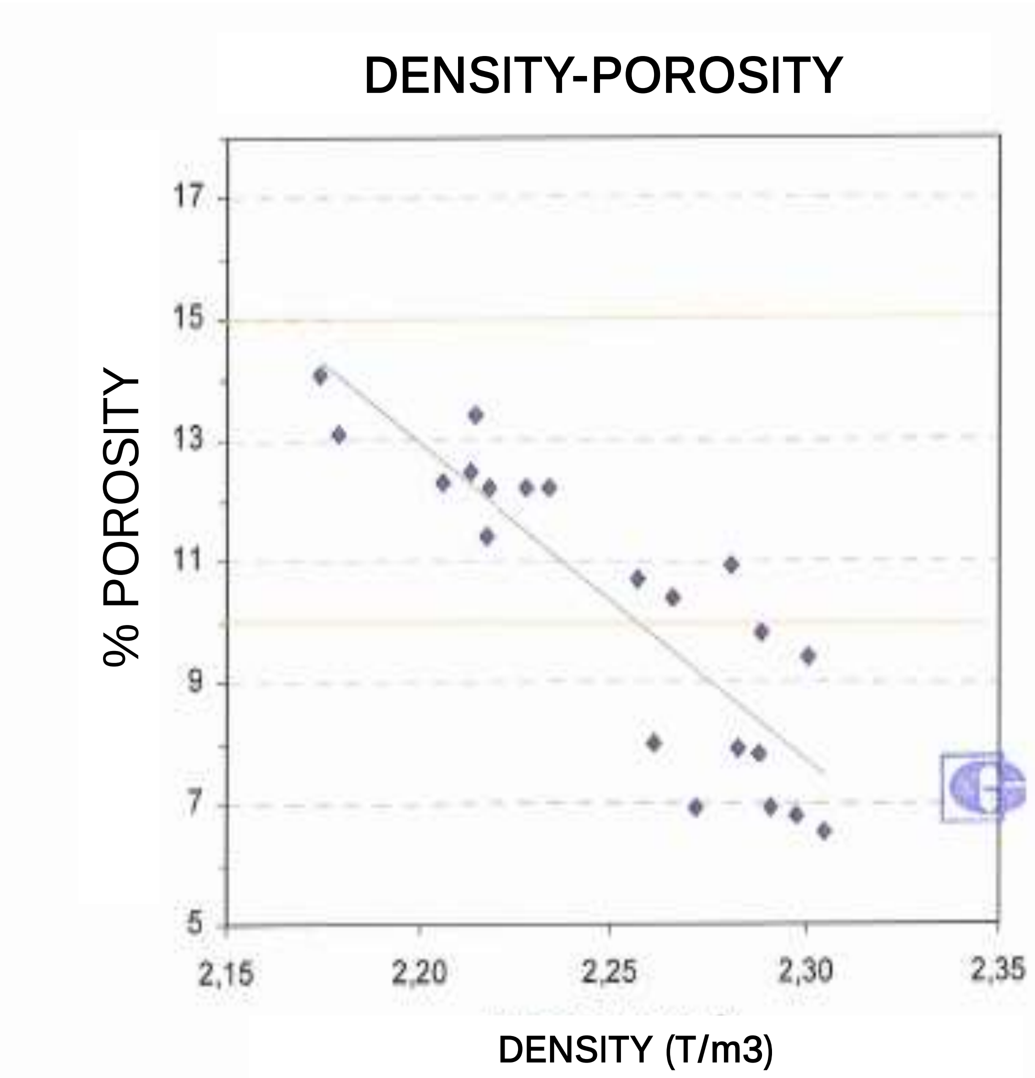
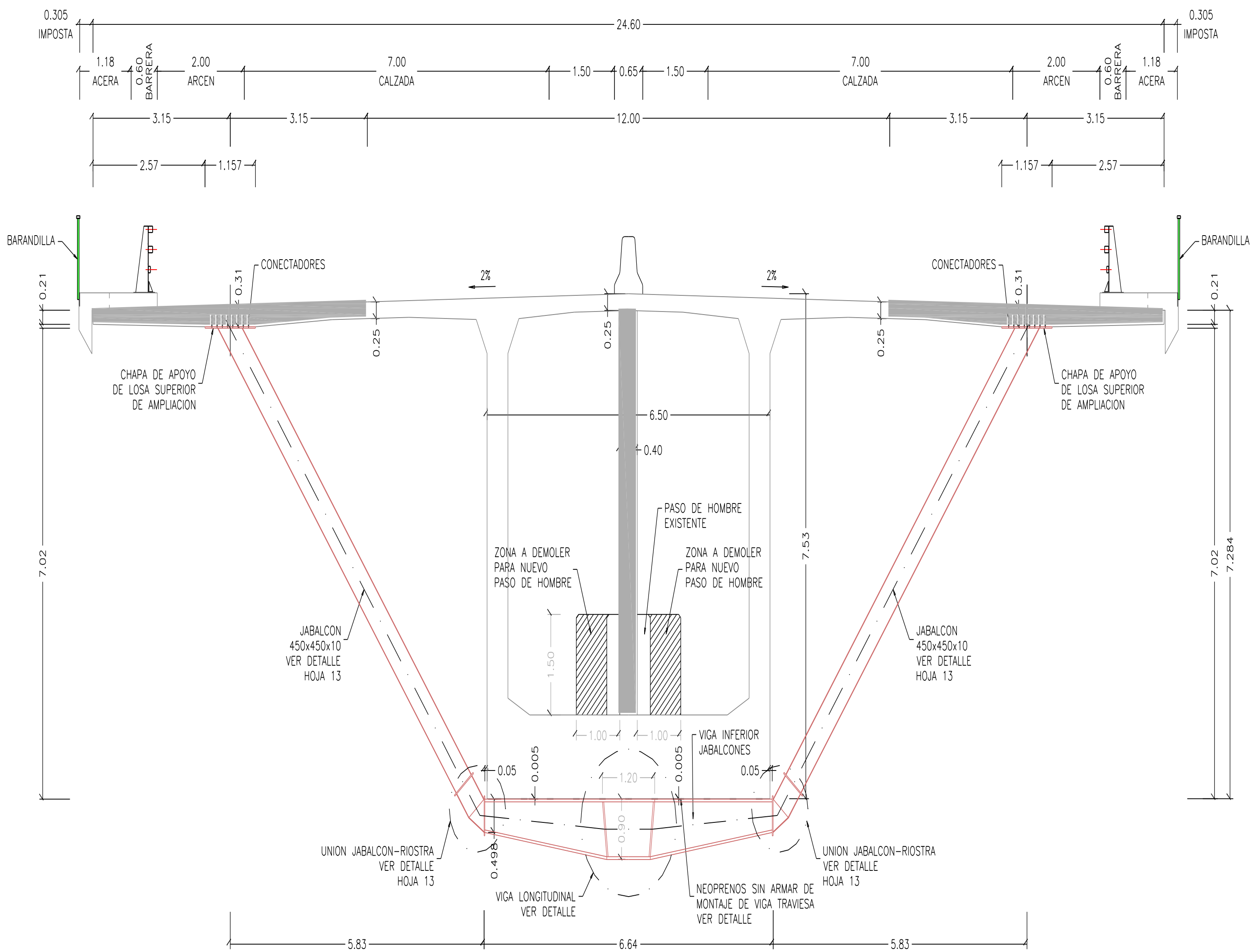


Structural Sustainability / Conceptual Design

Ponte Los Santos



Adopted cross-section

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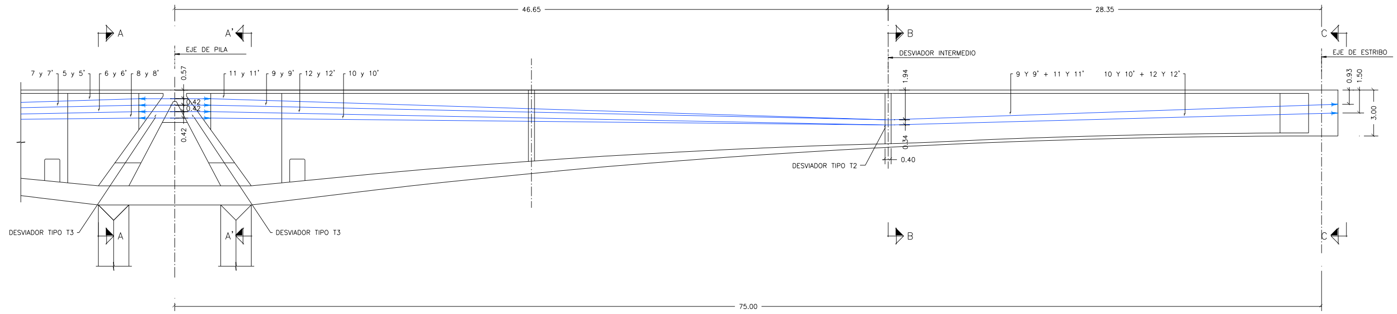
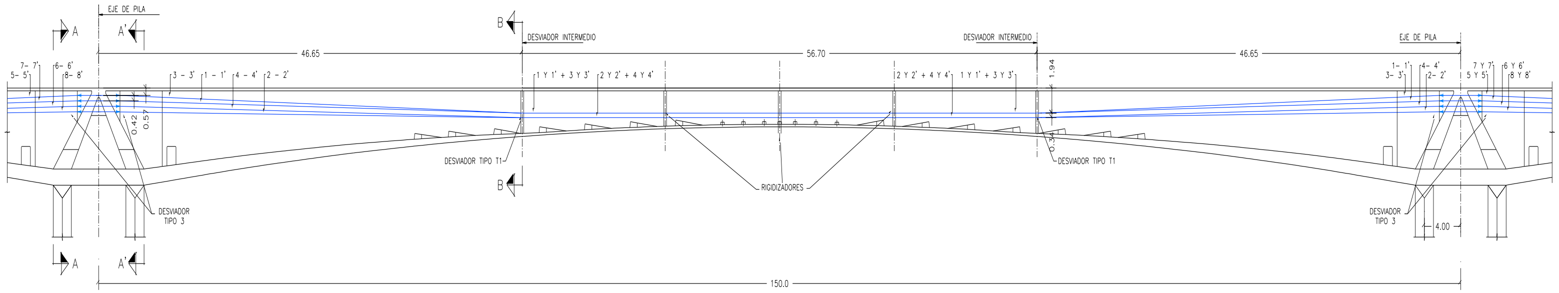
Ponte Los Santos

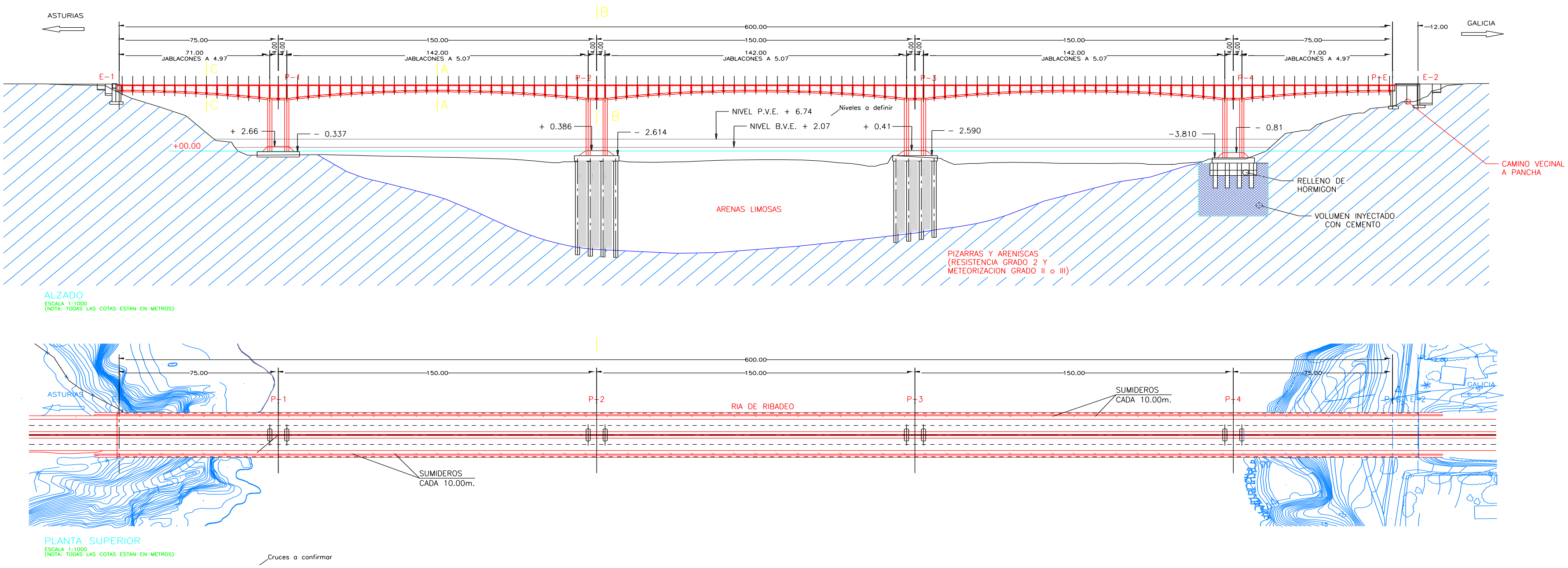




External prestressing

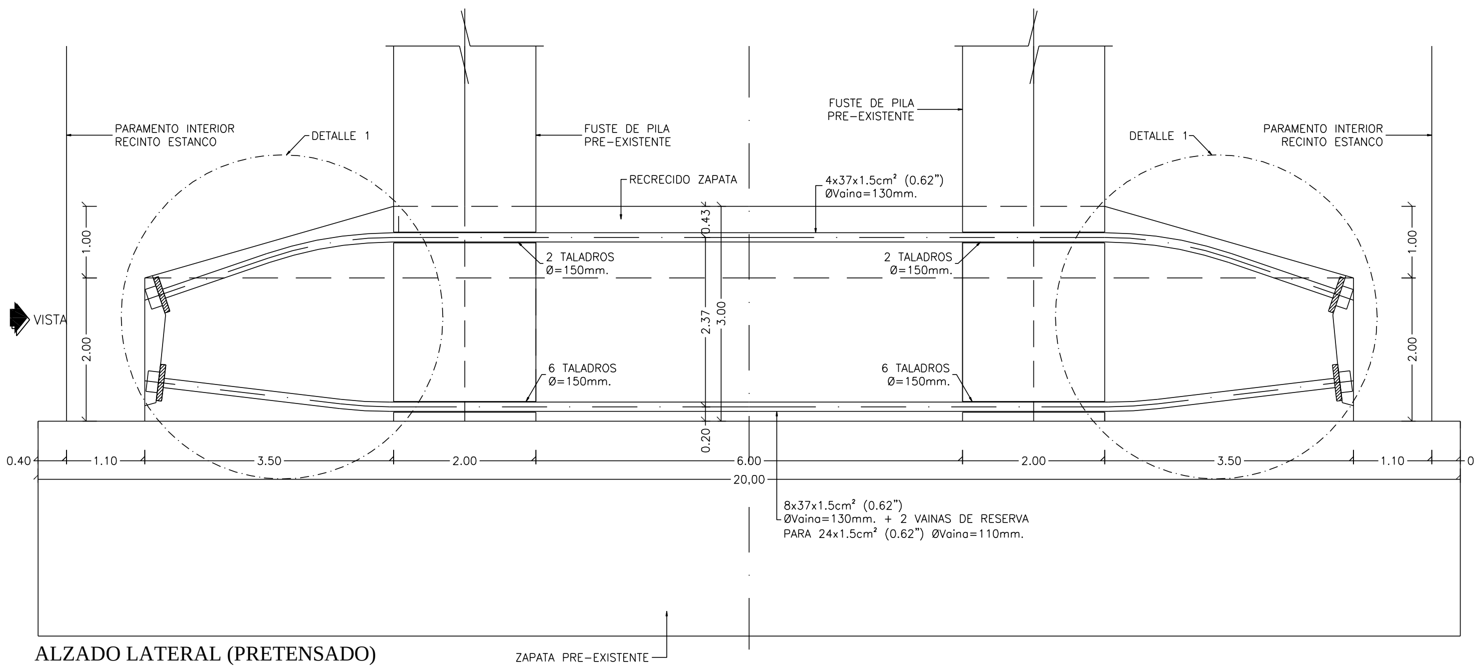
Structural Sustainability / Conceptual Design

Ponte Los Santos



Structural Sustainability / Conceptual Design

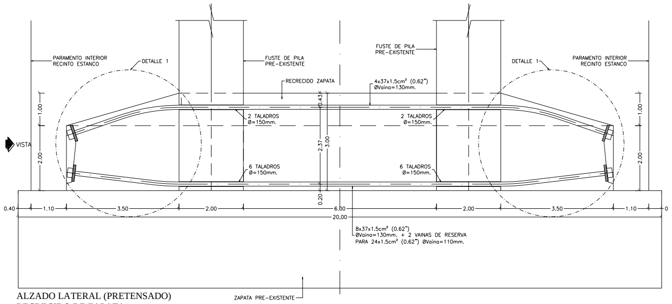
Ponte Los Santos



ALZADO LATERAL (PRETENSADO)
RECRECIDO DE ZAPATA

Structural Sustainability / Conceptual Design

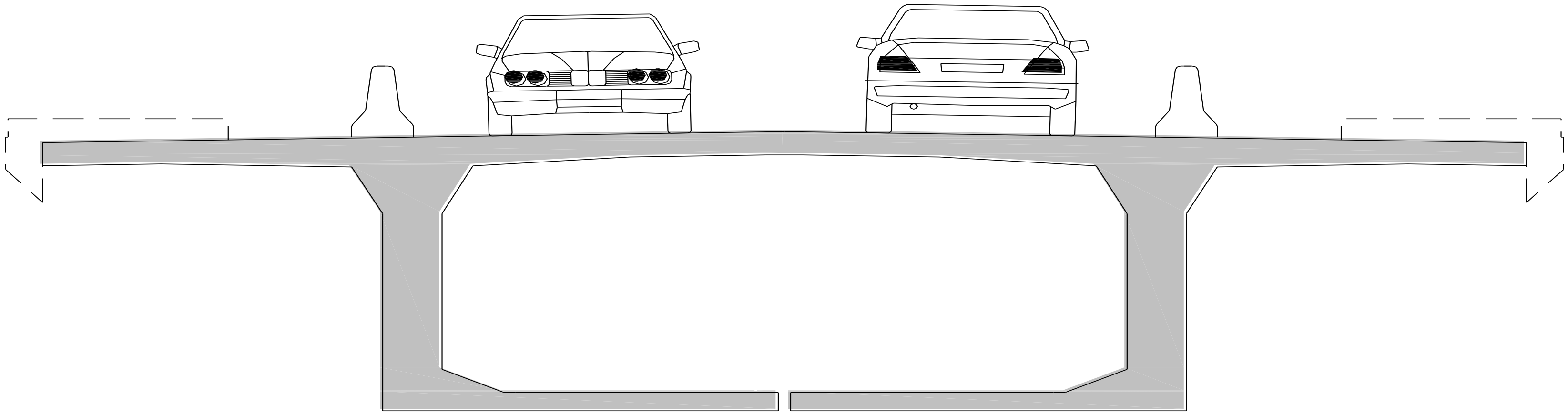
Ponte Los Santos

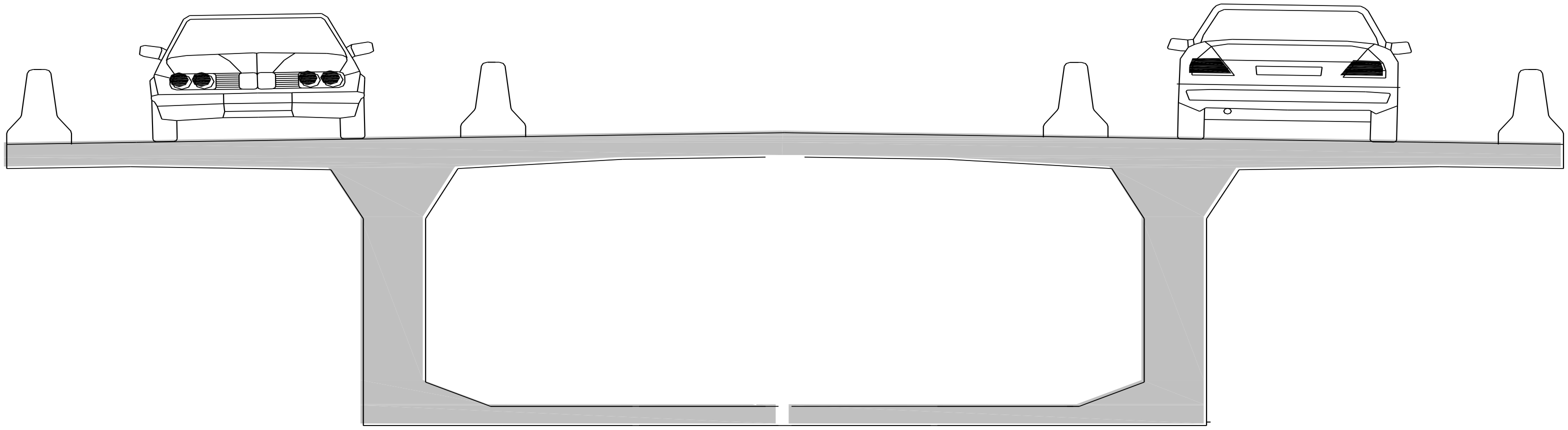


ALZADO LATERAL (PRETENSADO)
RECRECIDO DE ZAPATA

Structural Sustainability / Conceptual Design

Ponte Los Santos





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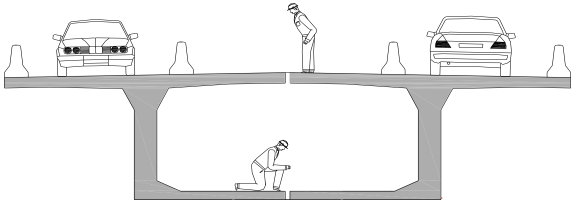
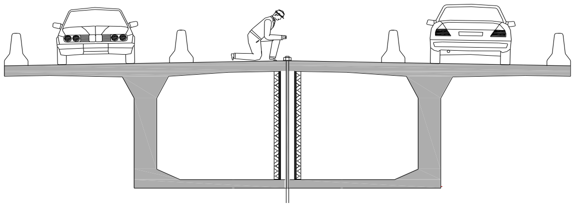
Structural Sustainability / Conceptual Design

Ponte Los Santos

Structural Sustainability / Conceptual Design

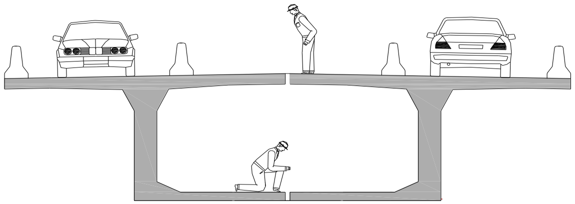
Ponte Los Santos

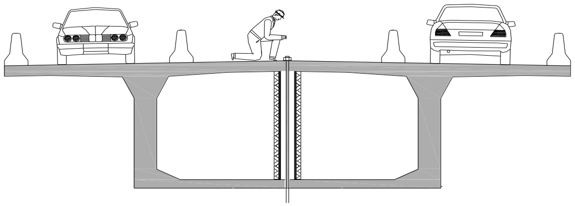




Structural Sustainability / Conceptual Design

Ponte Los Santos





Execution of the inner web

Structural Sustainability / Conceptual Design

Ponte Los Santos

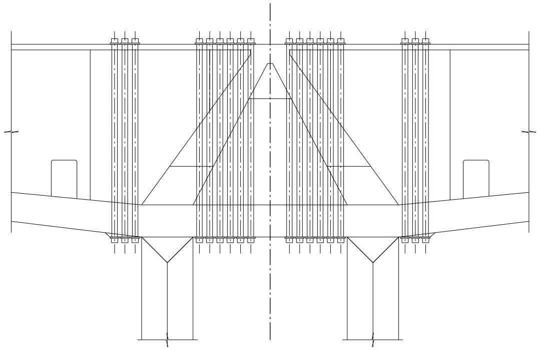




Execution of external prestressing inside the box-girder

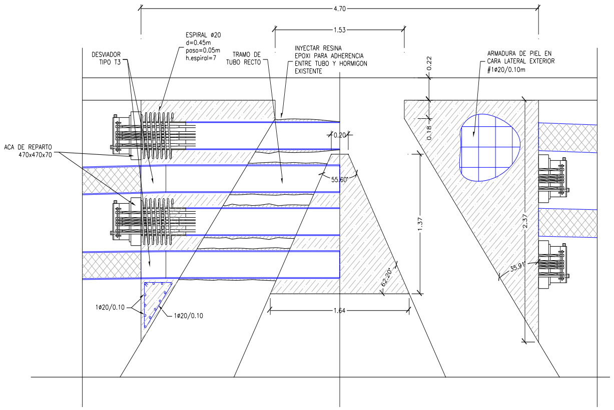
Structural Sustainability / Conceptual Design

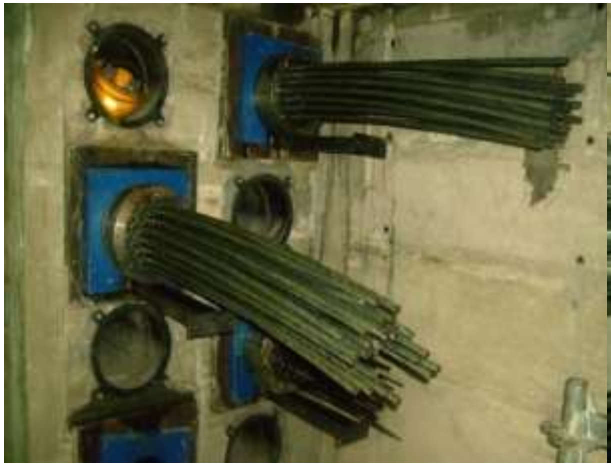
Ponte Los Santos



Structural Sustainability / Conceptual Design

Ponte Los Santos



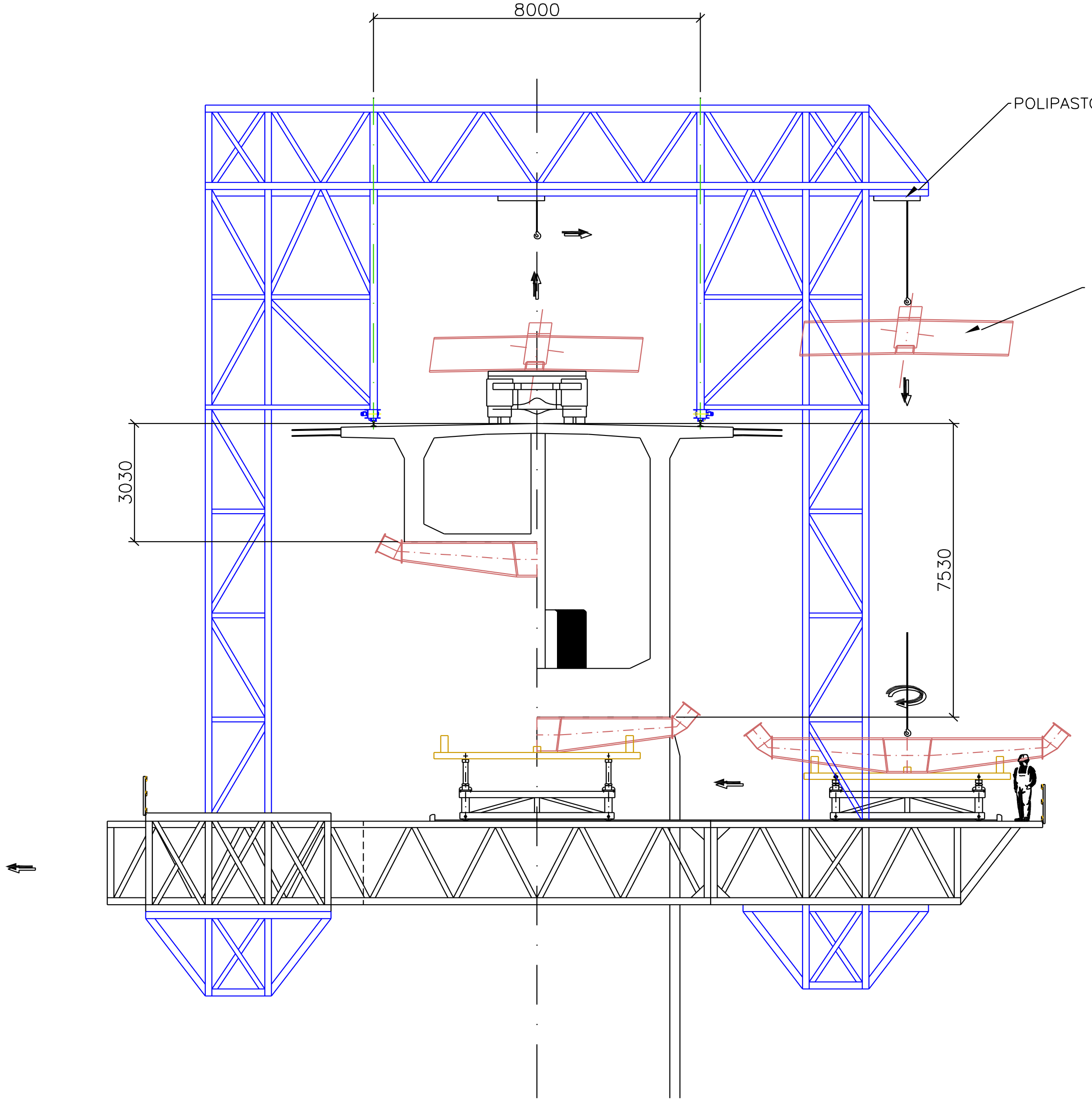


Structural Sustainability / Conceptual Design

Ponte Los Santos

Structural Sustainability / Conceptual Design

Ponte Los Santos



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Structural Sustainability / Conceptual Design

Ponte Los Santos

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Structural Sustainability / Conceptual Design

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Structural Sustainability / Conceptual Design

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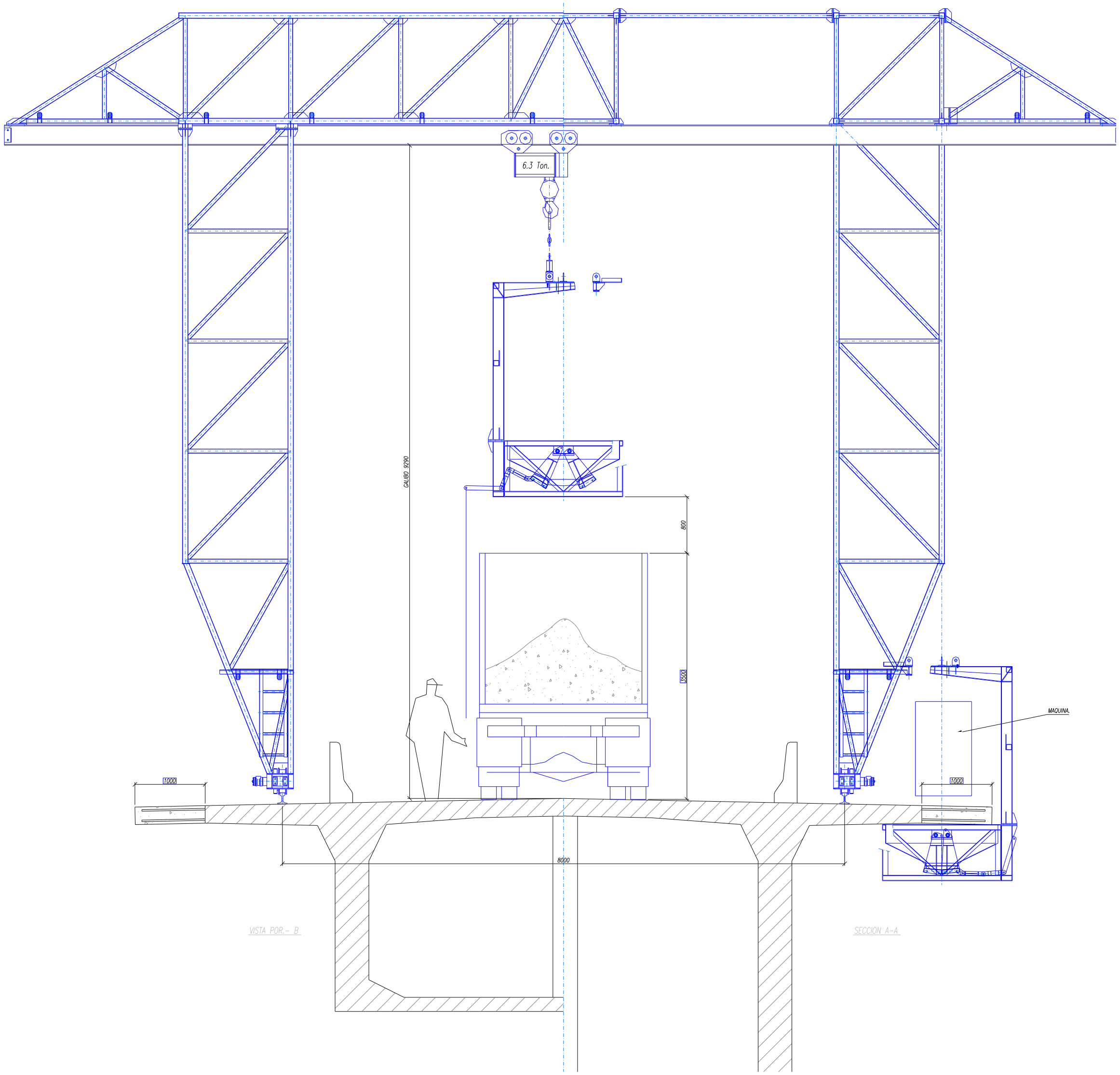
3 Structural Sustainability / Conceptual Design

Ponte Los Santos



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Structural Sustainability / Conceptual Design

Ponte Los Santos

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Structural Sustainability / Conceptual Design

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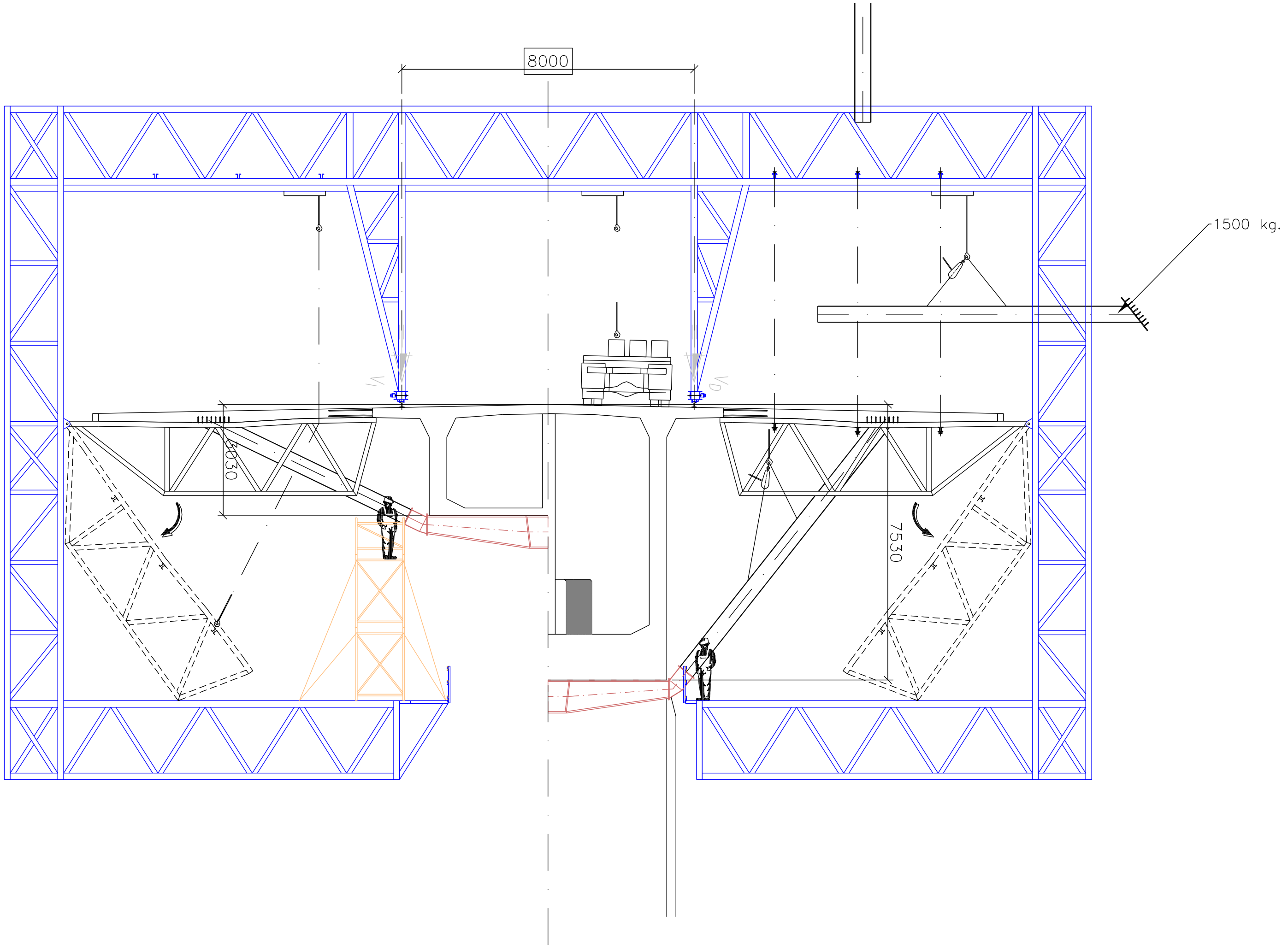

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Structural Sustainability / Conceptual Design

Ponte Los Santos

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Structural Sustainability / Conceptual Design

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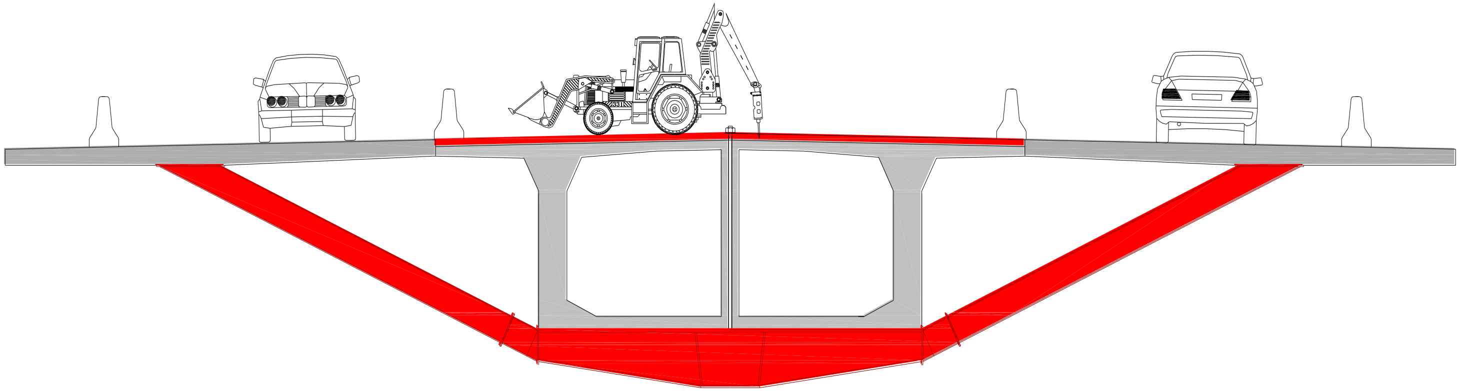

Structural Sustainability / Conceptual Design

Ponte Los Santos

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Structural Sustainability / Conceptual Design

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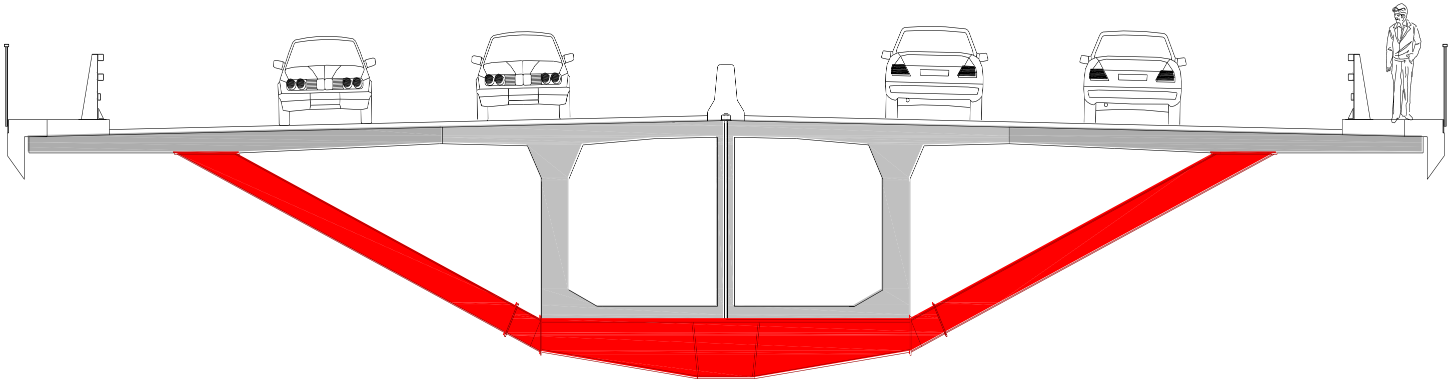
Structural Sustainability / Conceptual Design

Ponte Los Santos



Structural Sustainability / Conceptual Design

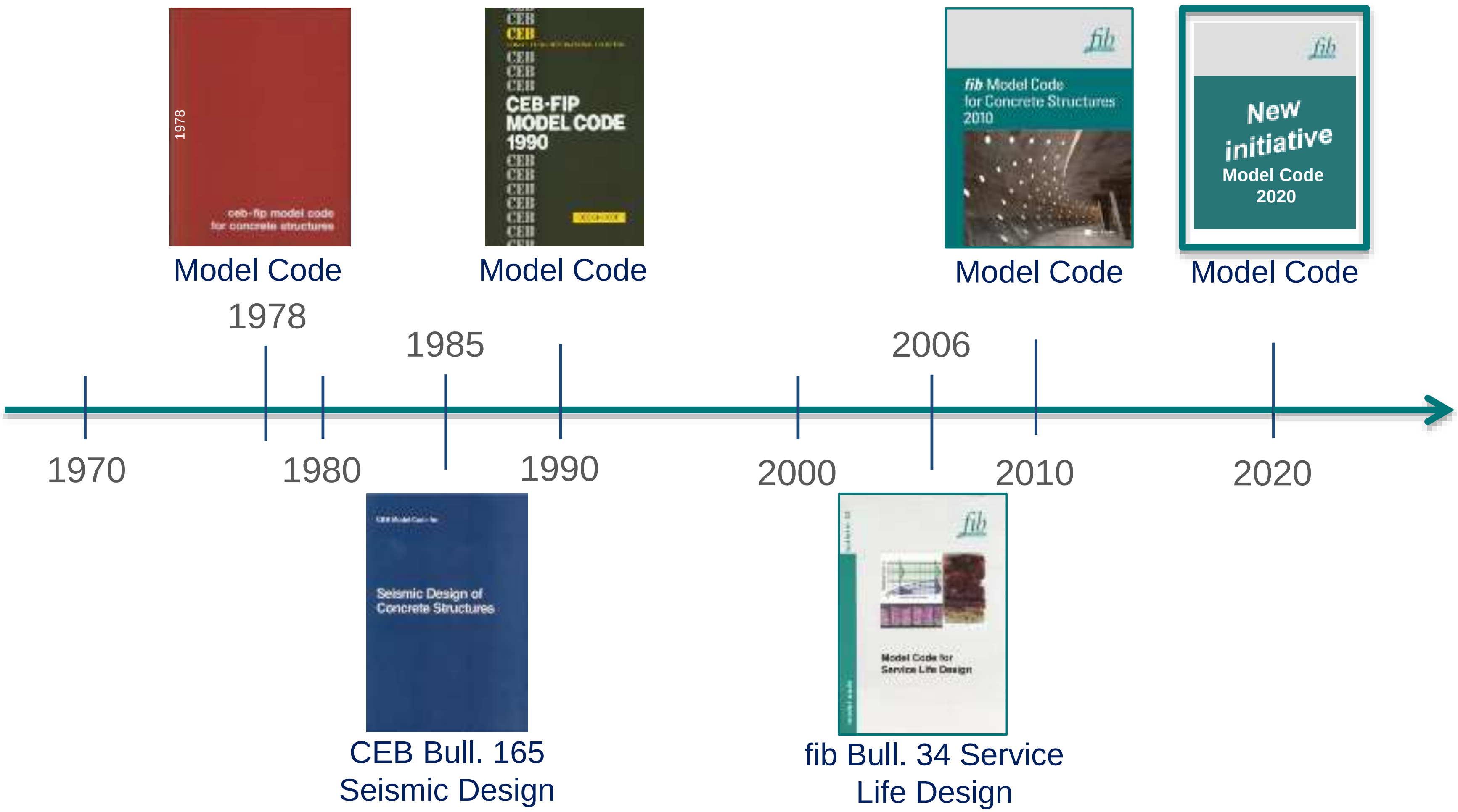
Ponte Los Santos

Structural Sustainability / Conceptual Design

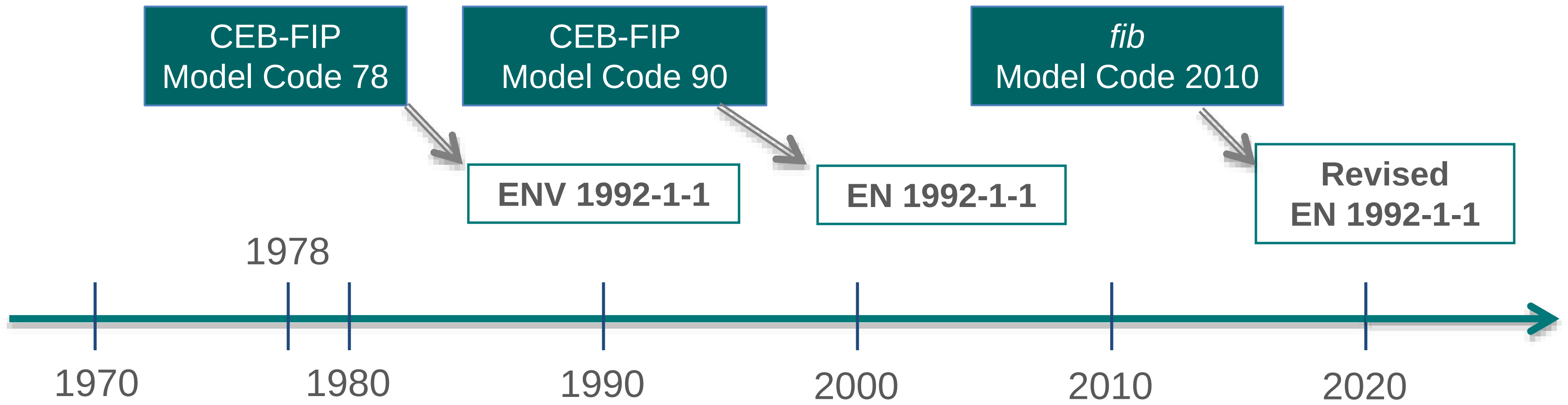
Construction 1936

Rehabilitation 2000

Evolução do Código Modelo



Strong influence on Eurocodes



Pronounced influence on Asian and African Model Codes

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

- MC 2020 will be a single, merged structural code for **new *and* existing structures**
- It Will be an **operational** model code and **oriented towards practical needs**
- 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 recognize the needs of engineering communities around the world. MC 2020 has to be a real **International Code**.

Basic Principles in MC2010

"Structures and structural members must be designed, constructed and maintained in such a way that they perform adequately and in an economically reasonable way during construction, service life and dismantlement."

"Structures and structural members must be able to contribute positively to the needs of humankind with regard to nature, society, economy and well-being."

Koji Sakai. Proposal for fib MC Revision. JCI-fib Joint Workshop, Tokyo, 1 September 2016

Recent Great Earthquakes in Japan (Hanshin, East Japan, Kumamoto)

- **Social aspects**
  - Loss of many lives, employment, and production bases by destruction of infrastructures and buildings, which depends on safety margin
- **Economic aspects**
  - Vast amount of cost to recover them
- **Environmental aspects**
  - Vast amount of resources and energy consumption to reconstruct them
  - Debris waste treatment

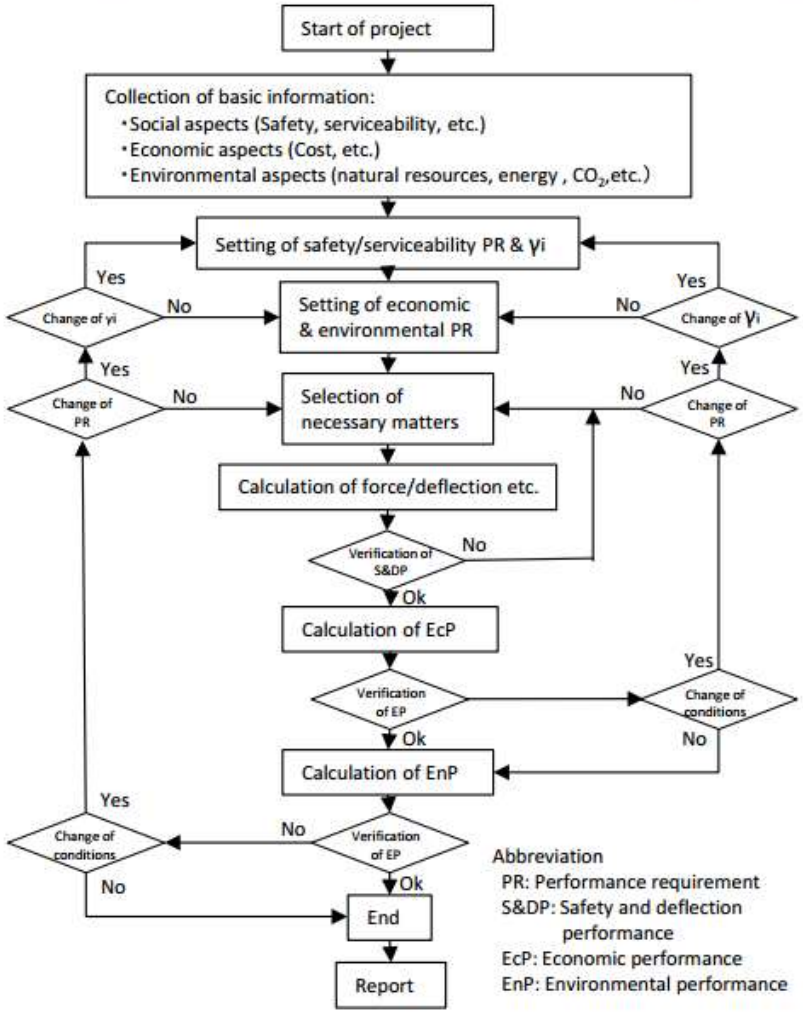
"All are interrelated and shall be comprehensively considered."

Koji Sakai. Proposal for fib MC Revision. JCI-fib Joint Workshop, Tokyo, 1 September 2016

Performance Requirements

- Safety and serviceability performance
  - same as in MC2010
  - but, consider γ_i (sustainability factor) for redundancy
- Economic performance
  - conceptual in MC2010 (in an economically reasonable way)
  - consider explicitly as a requirement
- Environmental performance
  - same as in MC2010
  - but, term "sustainability" is not used. Just write "*MC2020 is sustainability design system* (SDS)."
  - Environmental impact evaluation rules are available in ISO 13315.

Framework of Sustainability Design



Verification:

$\gamma_i S_d \leq R_d$

$\gamma_i \delta_d \leq \delta_a$

γ_i : Sustainability factor

Abbreviation
- PR: Performance requirement
- S&DP: Safety and deflection performance
- EcP: Economic performance
- EnP: Environmental performance

Koji Sakai. Proposal for fib MC Revision. JCI-fib Joint Workshop, Tokyo, 1 September 2016

Students of the School of Civil Engineering of the Technical University of Madrd during the presentation of the class assignment of the subject Structural Typology, created by Torroja

Education

El Greco – Doménikos Theotokópoulos (1541-1614)

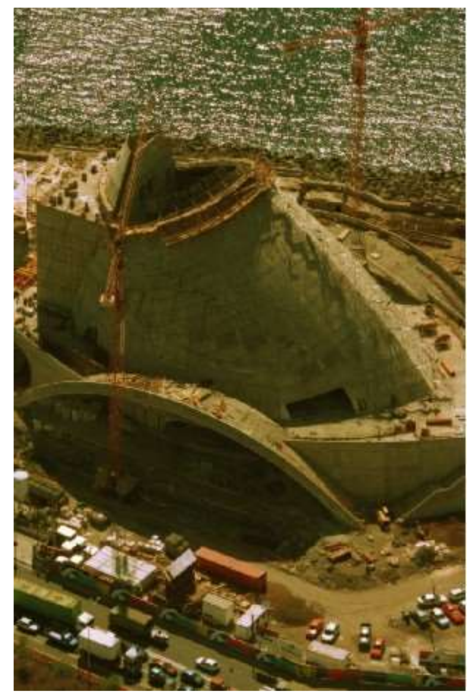
Pablo Picasso (1881-1973)

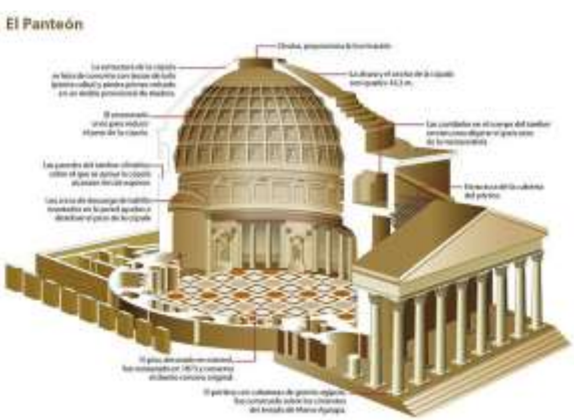
The value of history in other professions

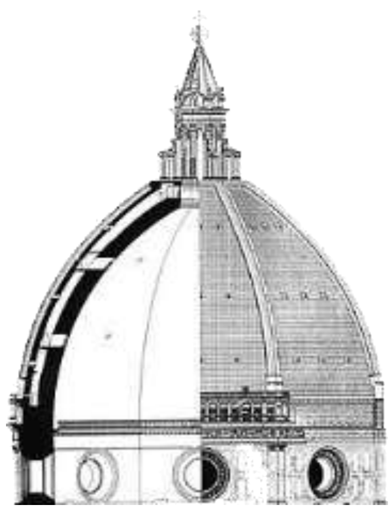
4

Education

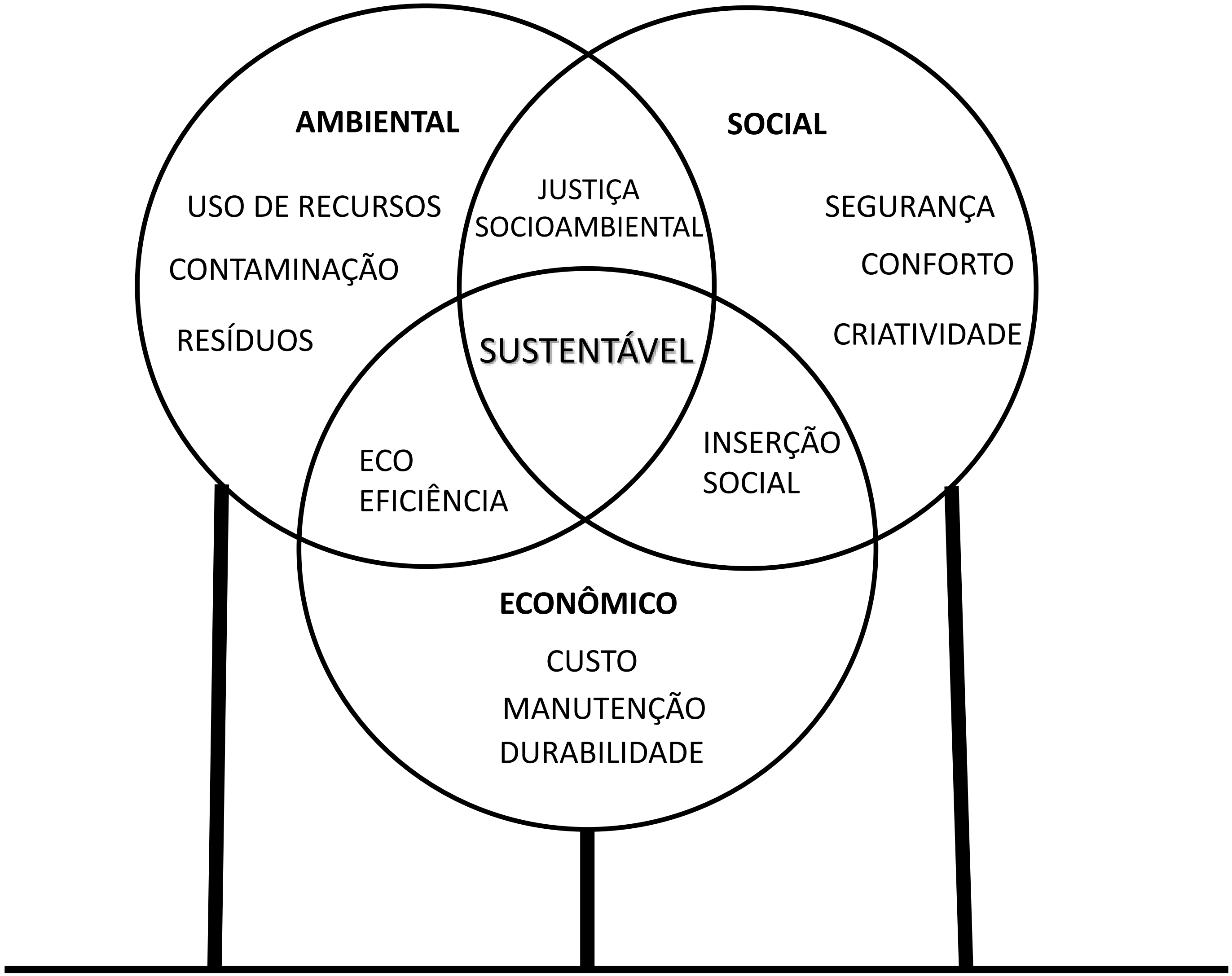
The value of history in other professions





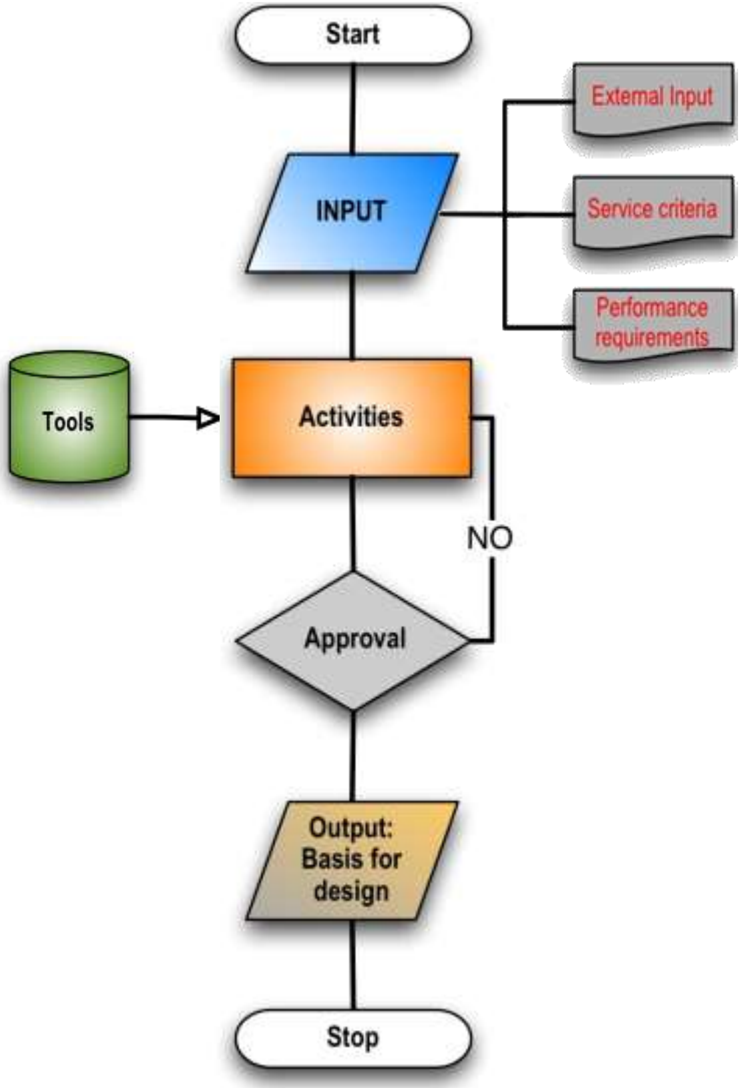


5 Final considerations



Final considerations

CONCEPTUAL DESIGN:
GENERAL PROCESS



Projeto conceitual é uma habilidade que se adquire com o tempo. Requer um grande esforço para entender os requisitos, sólido conhecimento de engenharia em diferentes disciplinas, para entender os problemas a serem solucionados. Requer cultura global, não somente em engenharia, mas também dos aspectos humanos, sensibilidade e uma grande ambição em descobrir a melhor solução. Requer experiencia, que é um processo de aprendizagem com os sucessos e falhas, um trabalho intenso e persistência. O projeto conceitual é necessário para todas atividades de engenharia.

Final considerations

Students of the School of Civil Engineering of the Technical University of Madrd during the presentation of the class assignment of the subject Structural Typology, created by Torroja

5 Final considerations

Ponte sobre o rio Burguillo Reservoir antes da construção

5 Final considerations

Final considerations

Ponte sobre o rio Burguillo Reservoir depois da construção

Hugo Corres Peiretti
Professor de Estruturas de Concreto na Universidade Politécnica de Madri
Vice presidente da fib
Fundador Fhecor Ingenieros Consultores

ENGENHARIA PARA UM MUNDO MAIS SUSTENTÁVEL