ENECE2023

26º Encontro Nacional de Engenharia e Consultoria Estrutural

SUSTENTABILIDADE NO PROJETO ESTRUTURAL

TENDÊNCIA OU REALIDADE?

fib CEB-FIP

ASSOCIAÇÃO BRASILEIRA DE ENGENHARIA E CONSULTORIA ESTRUTURAL ABECE

www.abece.com.br

www.fib-international.

TEMA PALESTRA

O Concreto Estrutural e a Sustentabilidade:

as ações da *fib* e a importância da pré-fabricação.

David Fernández-Ordóñez

fib Secretary General

International Federation for Structural Concrete
Fédération internationale du béton

O Concreto Estrutural e a Sustentabilidade: as ações da *fib* e a importância da pré-fabricação.

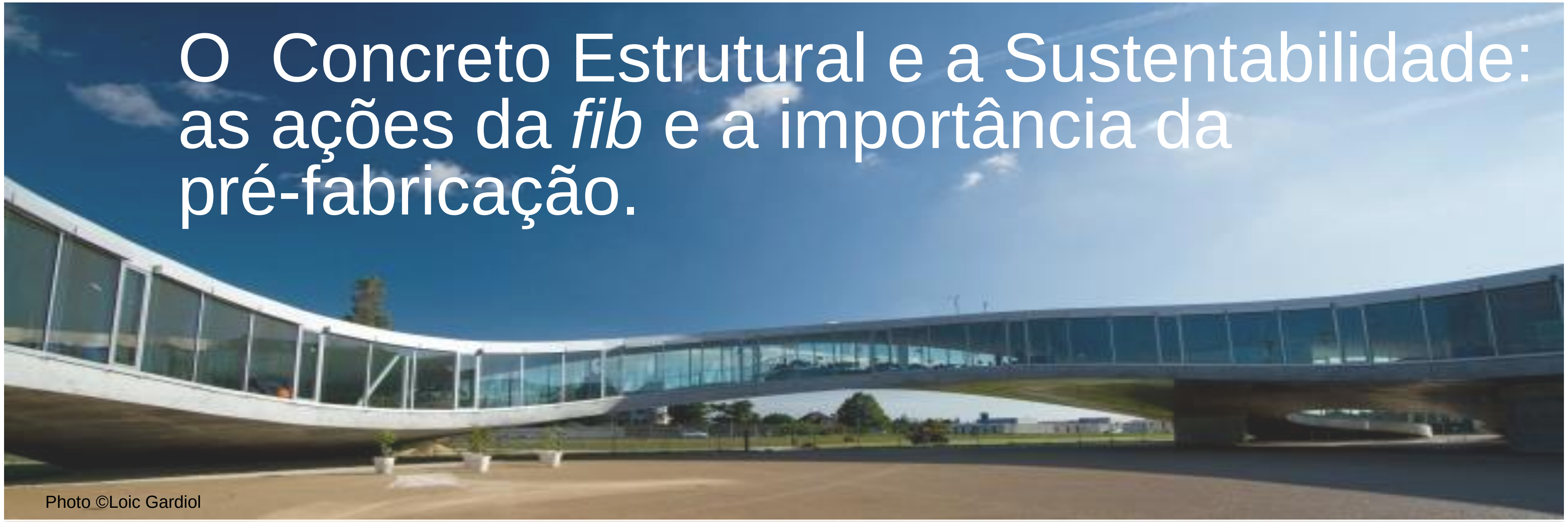


Photo ©Loic Gardiol

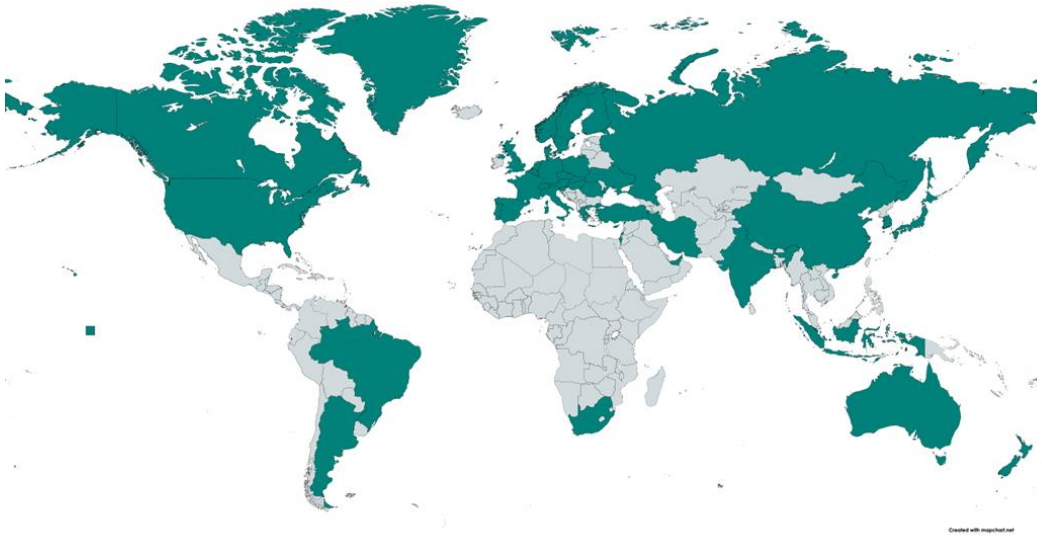
David Fernández-Ordóñez

fib Secretary General

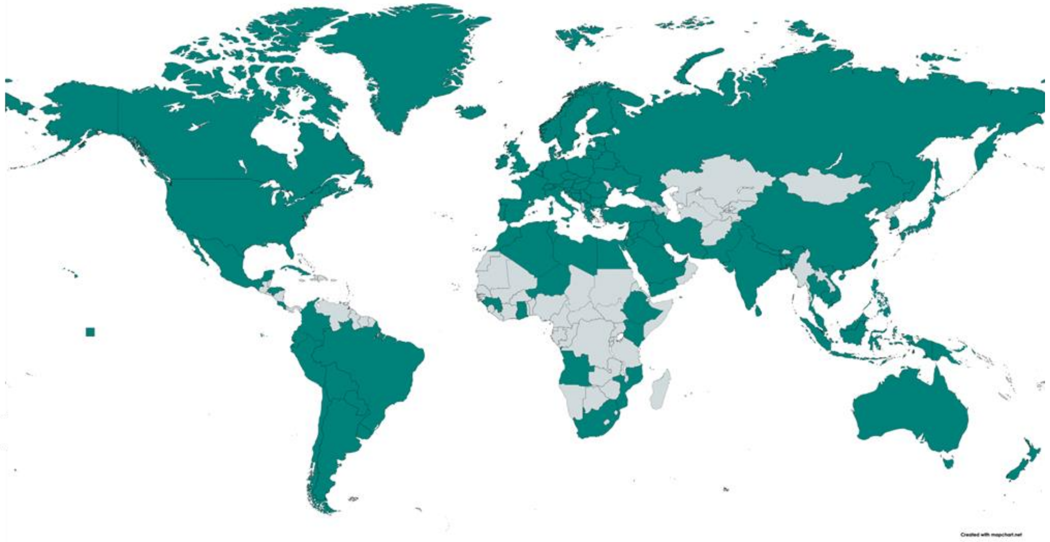
5 October 2023

Creation of the *fib*

40 *fib* statutory members



fib members in 104 countries

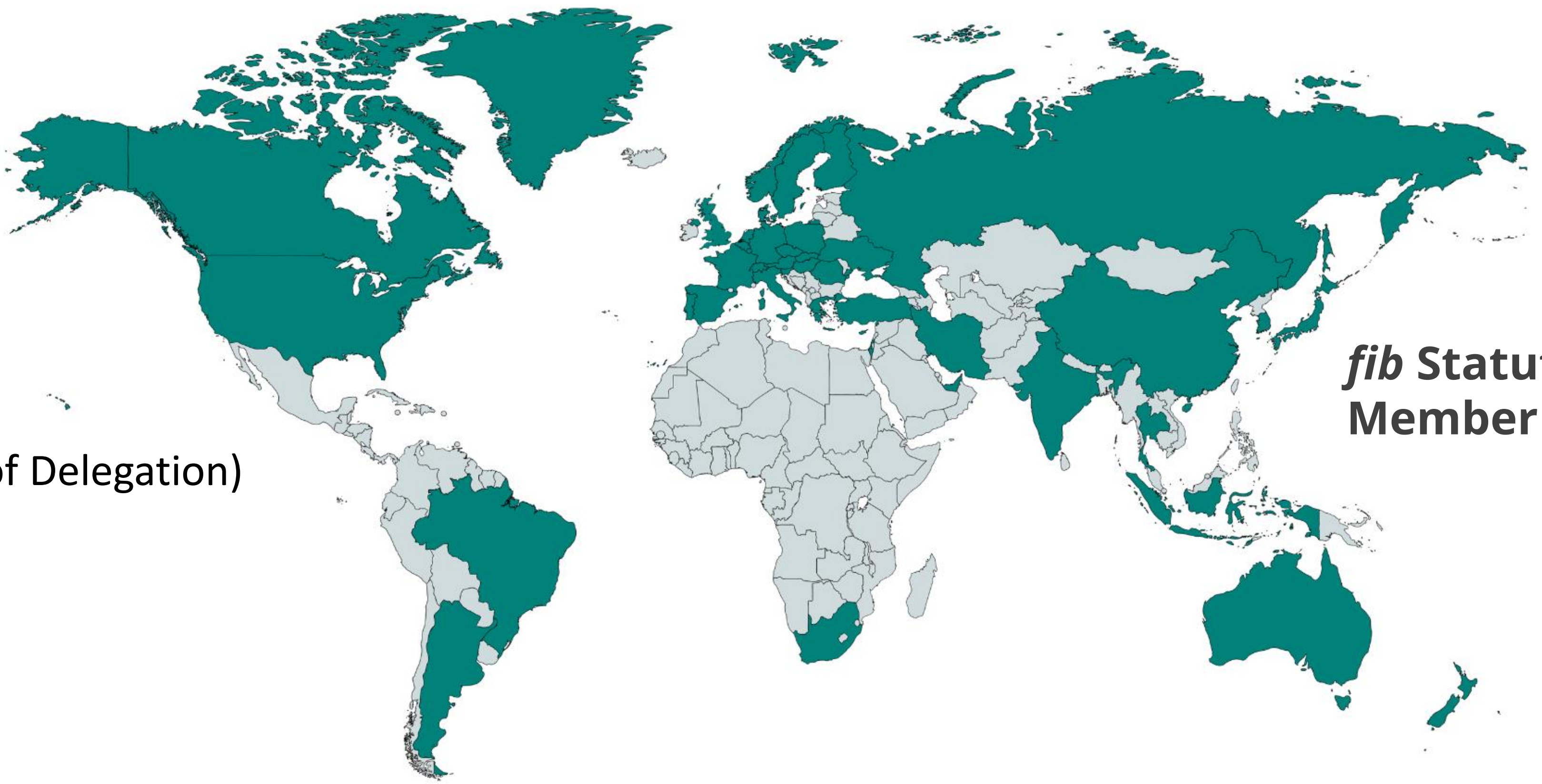


2023 Statutory member countries

NMG Organisations in Brazil
- Abcic
- Abece
- Ibracon

Delegates
- Fernando Stucchi (Head of Delegation)
- Iria Doniak
- Odinir Klein Junior
- Julio Timerman

Young Members Group
- Marcelo Melo



***fib* Statutory Member Countries**

40 *fib* Statutory Member Countries

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

Brazil in the *fib*

NMG Organisations in Brazil

- Abcic
- Abece
- Ibracon

Delegates

- Fernando Stucchi Head of Delegation
- Iria Doniak
- Odinir Klein Junior
- Julio Timerman

Young Members Group

- Marcelo Melo

Members from Brazil in the *fib*

- \+ 100 members or participants in TGs
- 44 Students and Young Members

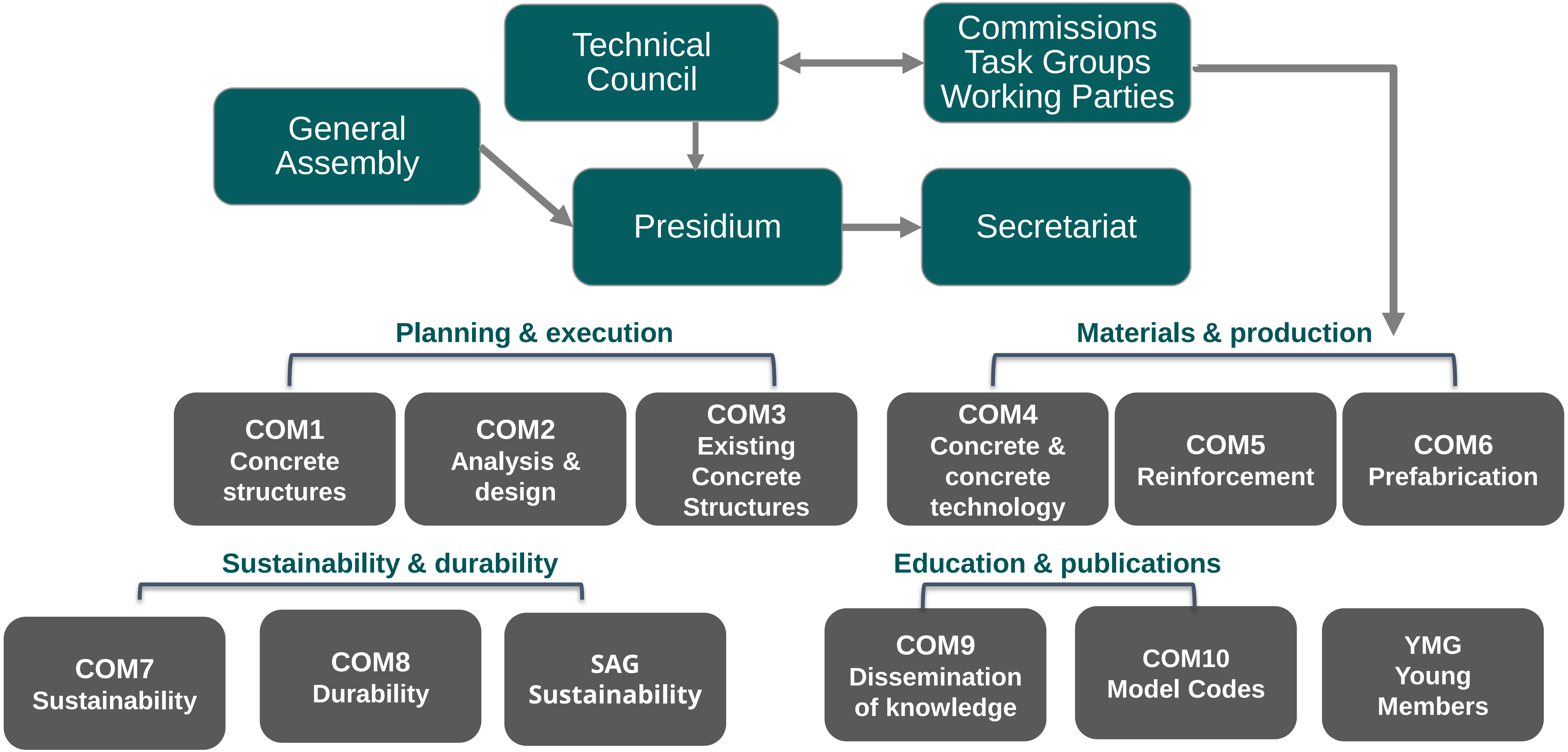
Persons in working groups

- Presidium and Deputy President:	Iria Doniak
- YMG Deputy Chair:	Marcelo Melo
- TG6.5 Precast bridges Convener:	Marcelo Waimberg
- TG6.9 Parking structures Convener:	Iria Doniak
- COM 5 member:	Pedro Almeida
- COM 6 member:	Mounir El Debs, Marcelo Ferreira, Iria Doniak
- COM 9 member:	Fernando Stucchi Iria Doniak
- COM 10 member:	Fernando Stucchi
- TG6.3 Sustainability:	Iria Doniak Paulo Helene

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*

The *fib's* structure



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2023-24 *fib* Presidium members

Stephen Foster
Australia
President

Iria Doniak
Brazil
Deputy President

Akio Kasuga
Japan
Past President

Agnieszka Bigaj
Netherlands

Marco di Prisco
Italy

Larbi Sennour
USA

Jean Michel Torrenti
France

Alberto Meda
Italy

Alfred Strauss
Austria

Sylvia Keßler
Germany

Steve Denton
UK

David Fernández-Ordóñez
Secretary General

A Bridge between Research and Practice

International Federation for Structural Concrete

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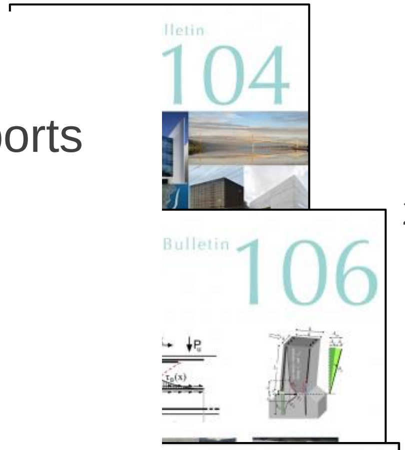
fib Bulletins

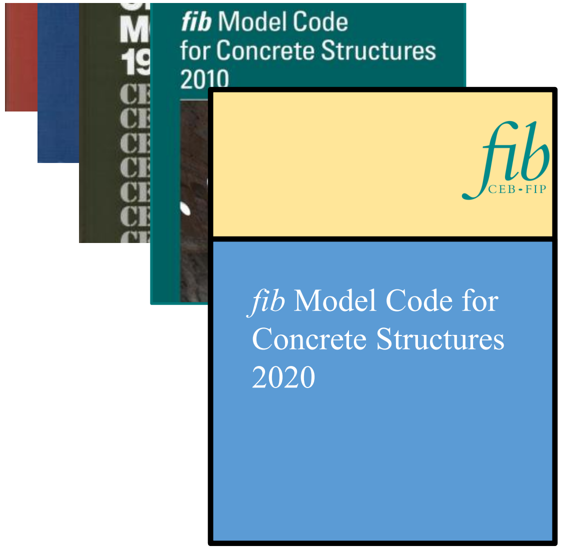
- Technical reports
- State-of-the-art reports
- Textbooks
- Manuals or guides
- Recommendations



Model Codes

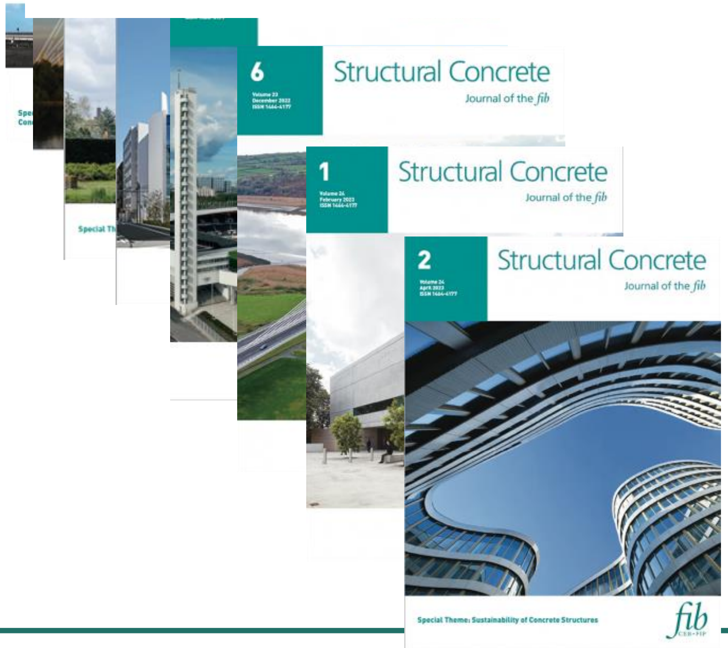
1978

- *fib* Model Code (2020) layout is underway



The *fib*'s journal *Structural Concrete*

- Current impact factor: **3.2**
- 6 issues per year



Access to the Publications of the *fib*

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PDF viewer

Rose Fitzgerald Kennedy Bridge

Rose Fitzgerald Kennedy Bridge N25, New Ross Bypass, Ireland

© Marcos Sánchez

The process of designing the Rose Fitzgerald Kennedy Bridge over the River Barrow spanned over 20 years from concept to completion.

The River Barrow Bridge provides the latest crossing point for the River Barrow which is at least 300 m wide at any point south of the town of New Ross. Located 30 km away from the sea, the bridge has been an engineering target for decades in Ireland. It provides a vital piece of infrastructure in the eastern corridor of the national roads network. Its completion removed a significant proportion of heavy traffic from the town of New Ross, enhancing the quality of life of the local communities while providing a much-needed reduction in long haul journey times in the south-east region.

The project was developed by Transport Infrastructure Ireland and their Technical Advisors Mott MacDonald Ireland in multiple stages. Between late 1998 and 2008, a concept design was developed during the planning and environmental studies stage and several alternatives were considered; from cable stayed to arches and balanced cantilevers, with a final preference for a three-tower extrados bridge which provided the right balance of slenderness and modest height towers. Tender for construction in a Public-Private Partnership (PPP) format took place in 2014, the contract was awarded in 2016 and the road was opened to traffic in January 2020.

The project, which includes a 12km long dual carriageway bypassing New Ross town, was tendered as a PPP Contract and awarded to BAM Iridium PPP Co with a team consisting of Dragados + BAM Ireland as contractors and Arup and Carlos Fernandez Casado S.L. as designers.

The design and value engineering of the structure was constrained by the requirements already established during planning as part of the Environmental Impact Statement and covered in Construction Requirements (critical documents in the Irish planning and tendering process). The following constraints, amongst others, were established as fixed:

- The exact position of the three towers (thus fixing the main spans to 230m).
- The height of the pylons (causing the bridge to be an extrados structure and limiting the cable angle to less than 12 degrees).
- The clear envelope for the navigational river channel (117m wide and 36m high over Mean High-Water Spring).
- The requirement for a full concrete section for the deck and pylons (at least the outside surfaces) and the requirements of a "closed" section with inclined webs without props or ribs.
- The maximum deck depth at the central pylon of 8m and at midspan of 3.5m.
- The position of a central pylon and a central plane of cables in cross section.
- The maximum height of the abutments over ground level of 10m.

With all the above constraints, the number of variables to optimise the design was limited to the cable spacing, number and size, along with the cross-section configuration for the main spans. There was also room to tweak the road design, both in plan and elevation, on the approaches and the configuration of the side spans.

Working within the challenging constraints listed above, the detailed design phase aimed to optimise the preliminary design concept of the structure for structural efficiency and material savings. To achieve a world record span in concrete for an extrados structure with a significant slenderness, the following changes were made:

The cross section was modified from inclined outer webs to two vertical webs 8m apart, substituting the outer webs with precast panels to maintain the appearance of a closed section. The precast panels contribute to the transversal behaviour but there is a gap of 20mm between each panel longitudinally, so they do not contribute to the longitudinal direction.

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Winner

Civil Engineering Structures

The initial proposal of three parallel cables was substituted by a single cable, spaced 6.5m longitudinally and with a maximum size of 127 strands. Saddles were proposed for the cable detail passing on the pylons, allowing the pylon width to be reduced from 2.6m to 1.6m, to enable the minimum possible deck width.

To maintain a relatively light deck, the web and slab thickness were minimised using high strength concrete, where required. C80/95 concrete was used in the main spans and C60/75 in the side spans where the compression required this strength, while the approach spans were designed as C50/60.

Finally, minor adjustments to the side spans were implemented to optimise the longitudinal behaviour. The road alignment was also modified to reduce the bridge width on both ends to achieve a constant width cross section, where possible, and reducing the bridge length from 905m to 887m by changes in the vertical alignment.

The bridge's final configuration, after the minor span changes during tender, resulted in a total length of 887m, as already indicated, with an arrangement of 36 + 45 + 95 + 230 + 230 + 95 + 70 + 50 + 36m. In this way, the structure is characterised by 9 spans with 8 intermediate piers – P1 to P8 – and the 2 abutments – A1 and A2. The plan alignment is straight along 440m located approximately in the central part of the bridge and then curved with a transition from a radius of 720m to the straight alignment at both ends. The height of the deck above the ground or over the river reaches 40m and the height of the towers above the deck is 27.0m for the central tower (P4) and 16.2m for the two lateral ones (P3 and P5). These values imply tower height to span ratios of 0.07L for the side towers and 0.117L for the central tower (with L being the central span length). These are low values which lead to a classic extrados cable arrangement. In addition, the deck is only 3.5m deep at midspan (L/65), 8.5m at the central tower (L/27) and 6.5m at the side towers (L/35). These are quite slender parameters. It is also important to highlight the implication of the different heights of the towers. This leads to an asymmetric distribution of the cables along the main spans (8 from the side towers and 18 from the main tower). This asymmetry on the cable

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support on the main spans leads to different cantilever lengths during construction, the 8 cables from the lateral towers support approximately 90m while the main tower supports the remaining 140m of each span, resulting in a cantilever length during construction of 140m which would have equated to a 280m equivalent main span.

This asymmetry and the presence of a central tower also affect the contribution of the cable system under traffic loads, as the central tower provides relatively low contribution when asymmetric spans are loaded.

The Rose Fitzgerald Kennedy Bridge over the River Barrow is a milestone in the design and construction of bridges of this typology. As a world record breaker span with a full concrete deck, its design and construction represented a significant challenge. This was not only due to its size, but also the slenderness achieved and the geometrical constraints derived from the Environmental Impact Statement. The fact that this structure presents a very slender deck affects the load distribution between this element and the cable system. This leads to a behaviour more closely related with cable stayed bridges in comparison with other extrados bridges. From an aesthetic point of view, this bridge is also unique due to the difference in height between the central tower and the side towers. This creates an asymmetry in the cable arrangement in relation to the central spans. Because of the slenderness of the deck, 3.5m deep at the tip with a maximum cantilever of 140m and extremely shallow cables angles (10 degrees with the deck), the geometric deflection control during construction was especially complicated, with the added difficulties of early age properties of the high strength concrete mix used in the project.

OWNER Transport Infrastructure Ireland (TII)
AUTHORITIES' TECHNICAL ADVISOR Mott MacDonald
MAIN AUTHORS Miguel Angel Astiz Suarez & Marcos Sánchez
OTHER PARTICIPANTS Lucia Blanco Martin, Guillermo Ayuso Calle, Borja Martin, Miguel Angel Gil, Raul Gonzalez Aguilar, Cian Long, Claudia Sanroman, Alfonso Ramirez Marchena, Mary Bowe, John Iliff, Fergal Cahill, Pierre O'Loughlin, Joe Shinkwin, John Murphy, Mike Wade & Ron Yee
CONTRACTORS BAM Ireland & Dragados UK Ireland
SUBCONTRACTORS/SUPPLIERS Tensa, Rubrica, Roadstone & Banagher
OPENED TO TRAFFIC January 2020

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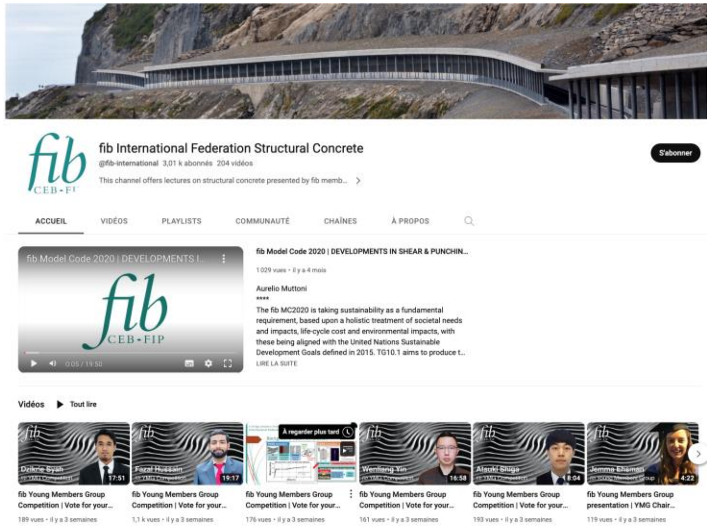
Let's keep in touch

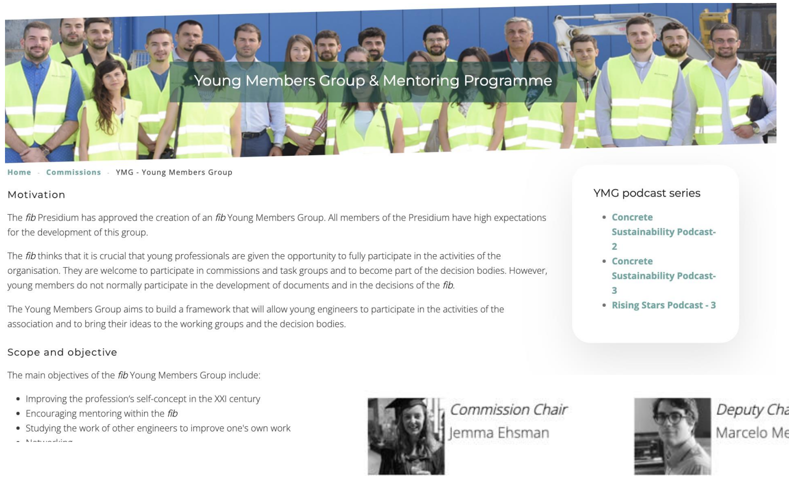
- Social media
- *fib*-news
- e-newsletter


fib-news
CEB-FIP
fib Bulletin 105
fib Bulletin 106

fib YouTube Channel



Join the *fib* Young Members Group!



- Events
- Podcast series
- YMG competition
- And more!

fib Young Members Group!

Home - Commissions - YMG - Young Members Group

Motivation

The *fib* Presidium has approved the creation of an *fib* Young Members Group. All members of the Presidium have high expectations for the development of this group.

The *fib* thinks that it is crucial that young professionals are given the opportunity to fully participate in the activities of the organisation. They are welcome to participate in commissions and task groups and to become part of the decision bodies. However, young members do not normally participate in the development of documents and in the decisions of the *fib*.

The Young Members Group aims to build a framework that will allow young engineers to participate in the activities of the association and to bring their ideas to the working groups and the decision bodies.

Scope and objective

The main objectives of the *fib* Young Members Group include:

- Improving the profession's self-concept in the XXI century
- Encouraging mentoring within the *fib*
- Studying the work of other engineers to improve one's own work

YMG podcast series

- **Concrete Sustainability Podcast-2**
- **Concrete Sustainability Podcast-3**
- **Rising Stars Podcast - 3**

Deputy Chair
Marcelo Melo

Next events

fib **PhD Symposium 2024 in Budapest, Hungary**

28-39 August 2024

fib **ICCS24 Sustainability in Guimarães, Portugal**

11-13 September 2024

fib **Symposium 2024 in Christchurch, New Zealand**

11-13 November 2024

fib **International Symposium on Conceptual Design of Concrete Structures, 2025 Rio de Janeiro, Brazil**

14-15 May 2025

fib **Symposium 2025 in Antibes, France**

16-18 June 2025

Home · Commissions · COM6: Prefabrication

Motivation

Prefabrication plays an important role in the construction of concrete structures worldwide and is evolving continuously to cope with current society's habits and needs related to housing, commercial buildings and civil engineering works. In fact, industrialised construction may result in cost efficiency, good quality and environmentally friendly solutions, as well as the ability to adapt to market demands.

Scope and objective of technical work

The basic goal of COM6 is to enhance the progress of precast concrete, in relation to the state-of-the-art. The general scope is to promote the understanding of design concepts, technology and use of precast concrete, not only by the specialists but also by a broader audience. The implied objectives are:

- to stimulate and coordinate R&D internationally;
- to transfer the output into planning, practical design and construction, by means of technical reports, state-of-the-art reports, guides to good practice, handbooks;
- to disseminate knowledge through seminars, courses, educational material;
- to contribute to recommendations, pre-normative documents and codes within standardisation bodies.

COM6 addresses subjects that include items directly related to precast concrete, such as systems, elements, connections, production, handling, assembling, demounting, etc., as well as indirectly related items such as structural analysis, materials technology, building physics, equipment, environmental issues, sustainable development, terminology.

Commission Chair
Stef Maas

Deputy Chair
Wit Derkowski

Co Deputy Chair
Larbi Sennour

VIEW ALL MEMBERS

GET IN TOUCH

ACCESS NETWORK

DOCUMENTS

Commission 6. Prefabrication

Task Groups:

TG 6.1 Precast floors

Conveners: Maas (Belgium), Klein-Holte (Netherlands)

TG 6.2 Quality control for precast concrete

Convener: Frank (USA)

TG 6.3 Sustainability of structures with precast elements

Conveners: De la Fuente, Josa, Fernández-Ordóñez (Spain)

TG 6.4 Precast concrete towers for wind power generators

Convener: Lancha (Spain)

Commission 6. Prefabrication

Task Groups:

TG 6.5 Precast concrete bridges

Conveners: Waimberg (Brazil), Kata (Japan)

TG 6.6 Retrofitting of precast seismic structures

Convener : Pampanin (Italy)

TG 6.8 Terminology for precast concrete

Convener: Krohn (USA)

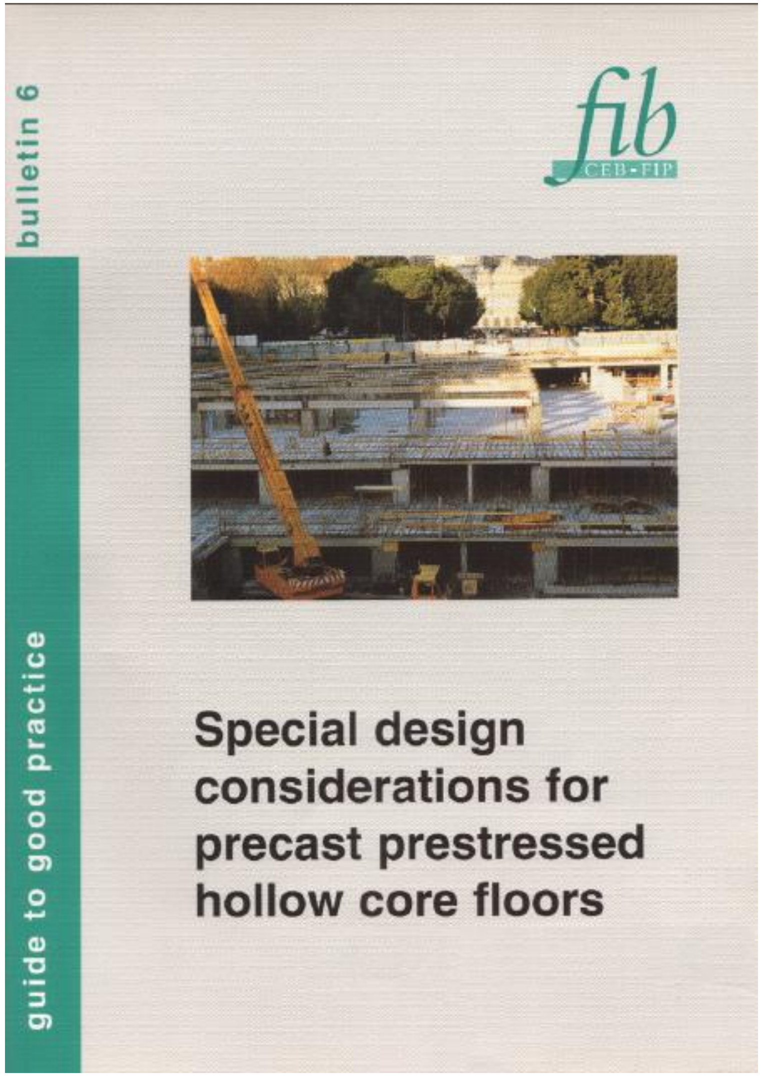
TG 6.9 Precast Parking Structures

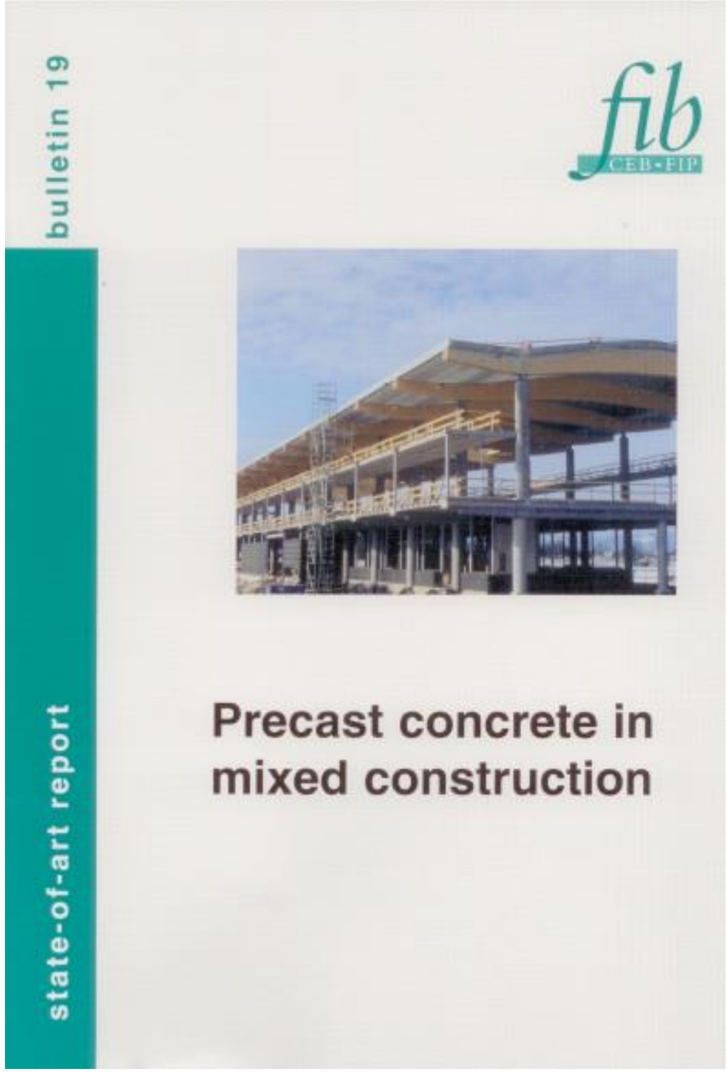
Conveners: Sennour (USA), Doniak (Brazil)

TG 6.11 Vision of precast concrete on social challenges

Convener: Falger (Netherlands)

fib Commission of Prefabrication. Publications





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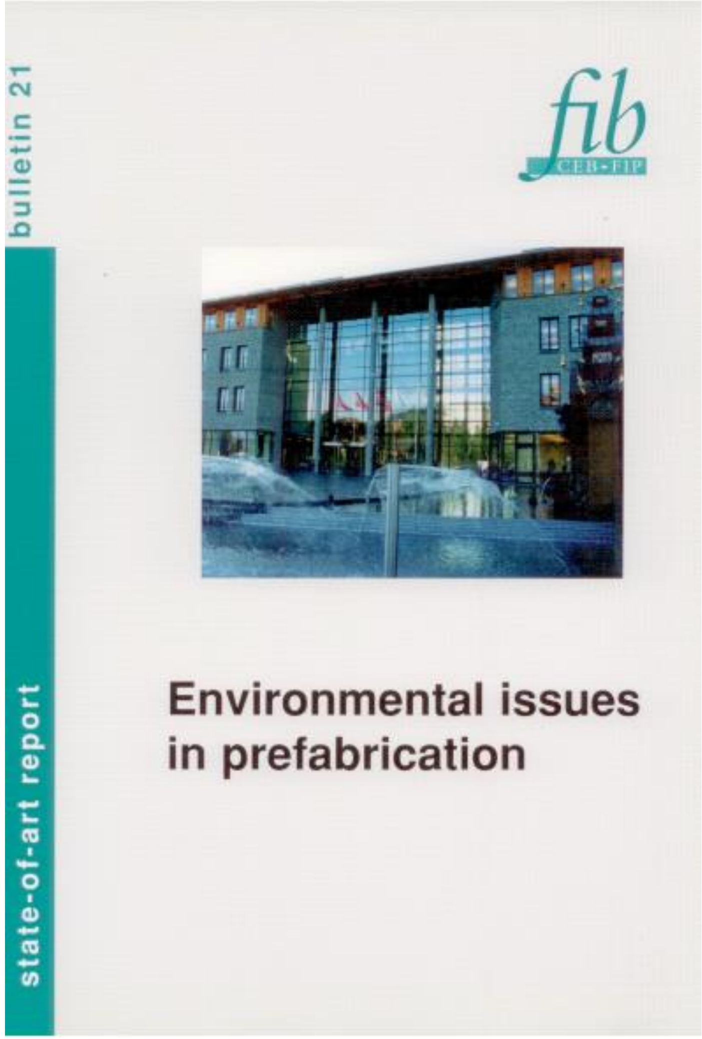

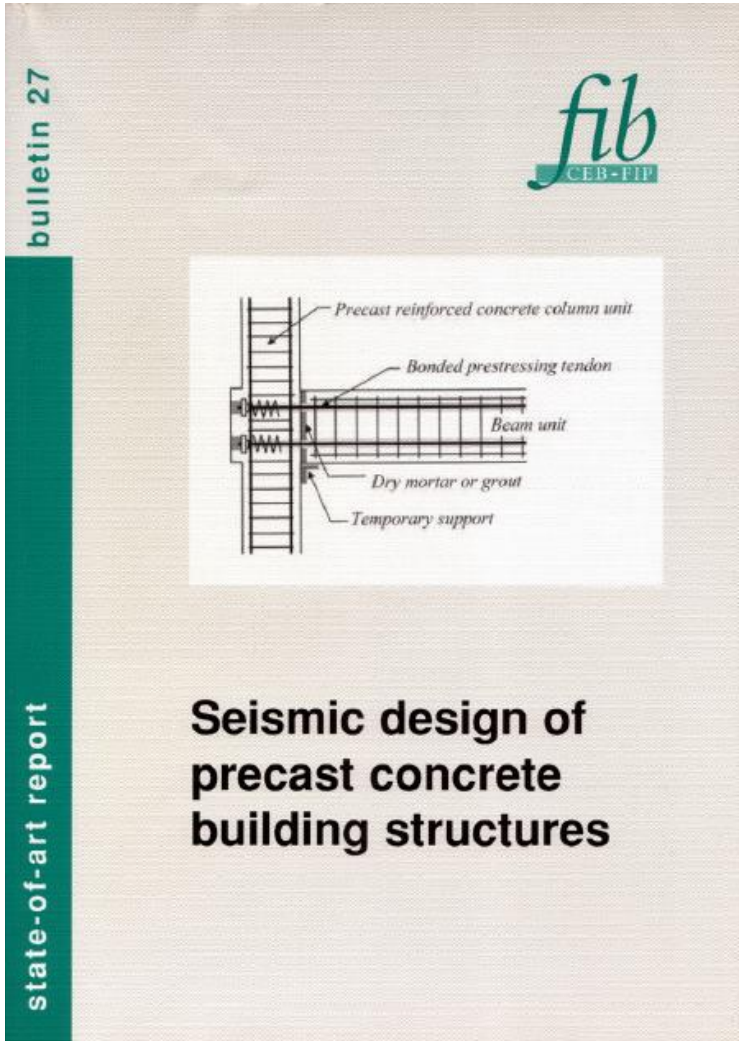

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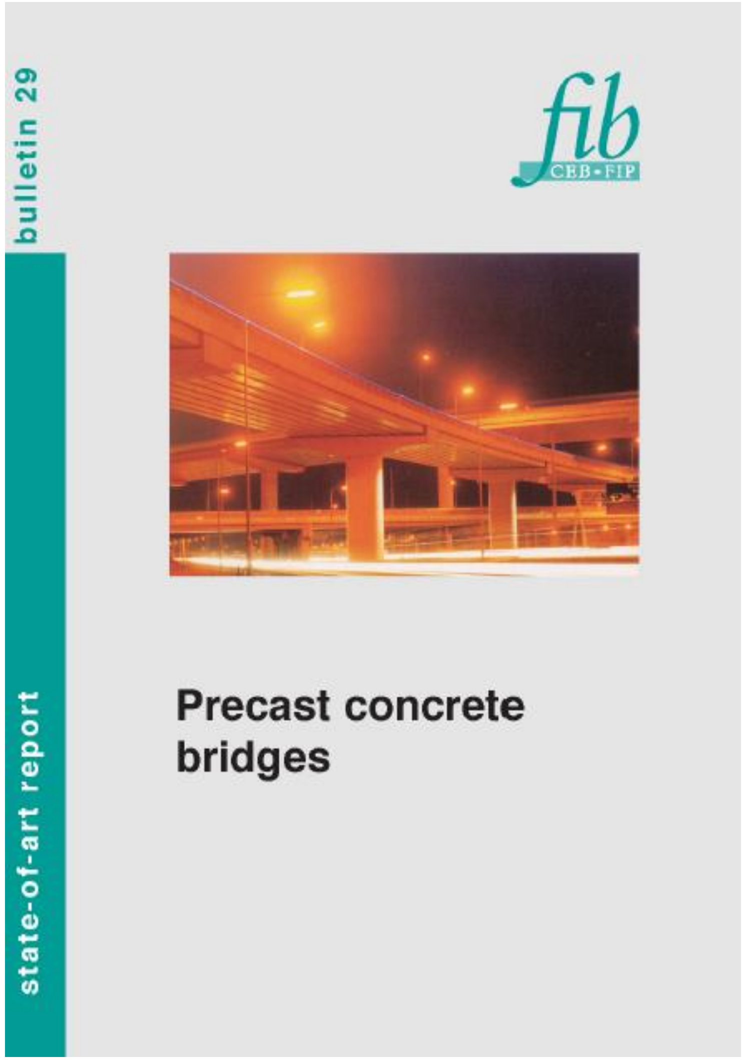

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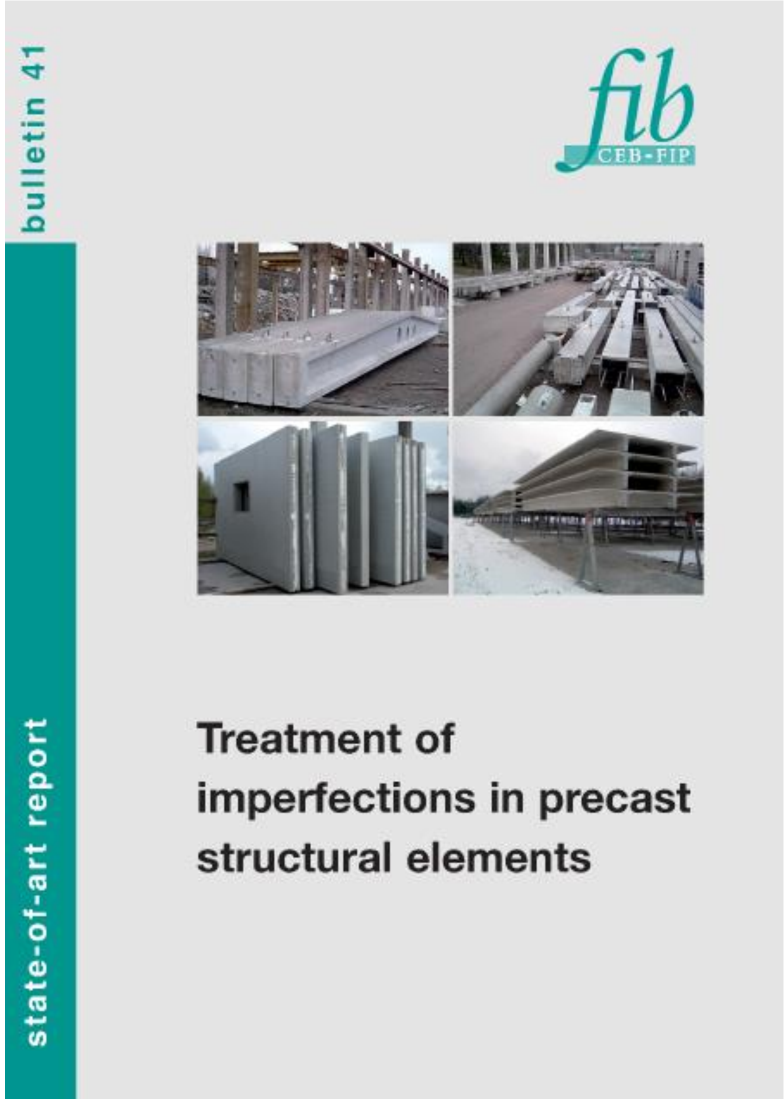

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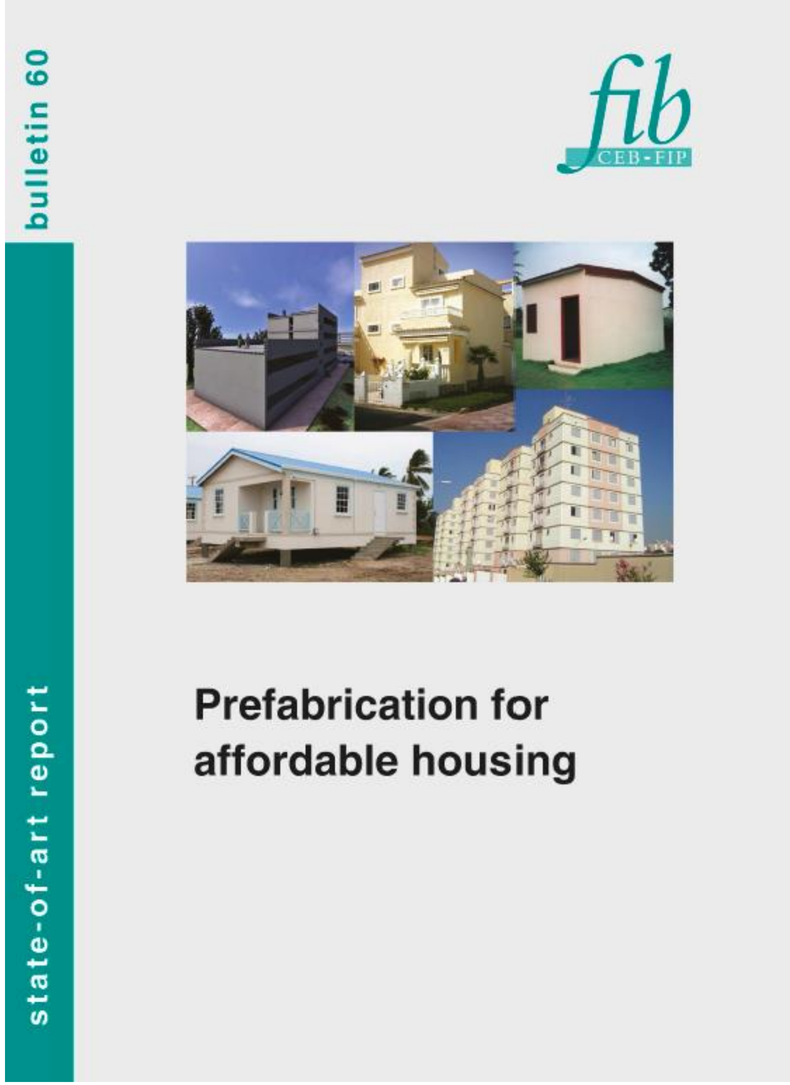

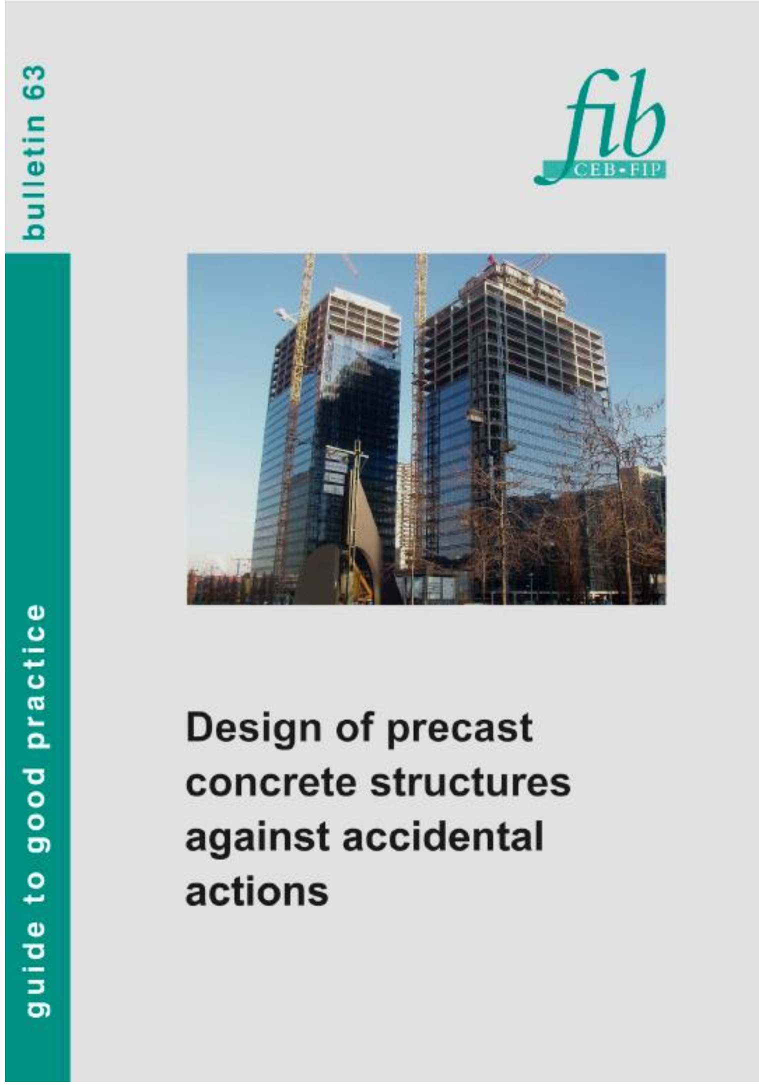

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Bulletin 74

manual - textbook

Planning and design handbook on precast building structures

ISSN 1562-3610
ISBN 978-2-88394-114-4

Planning and design handbook on precast building structures

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International Federation for Structural Concrete
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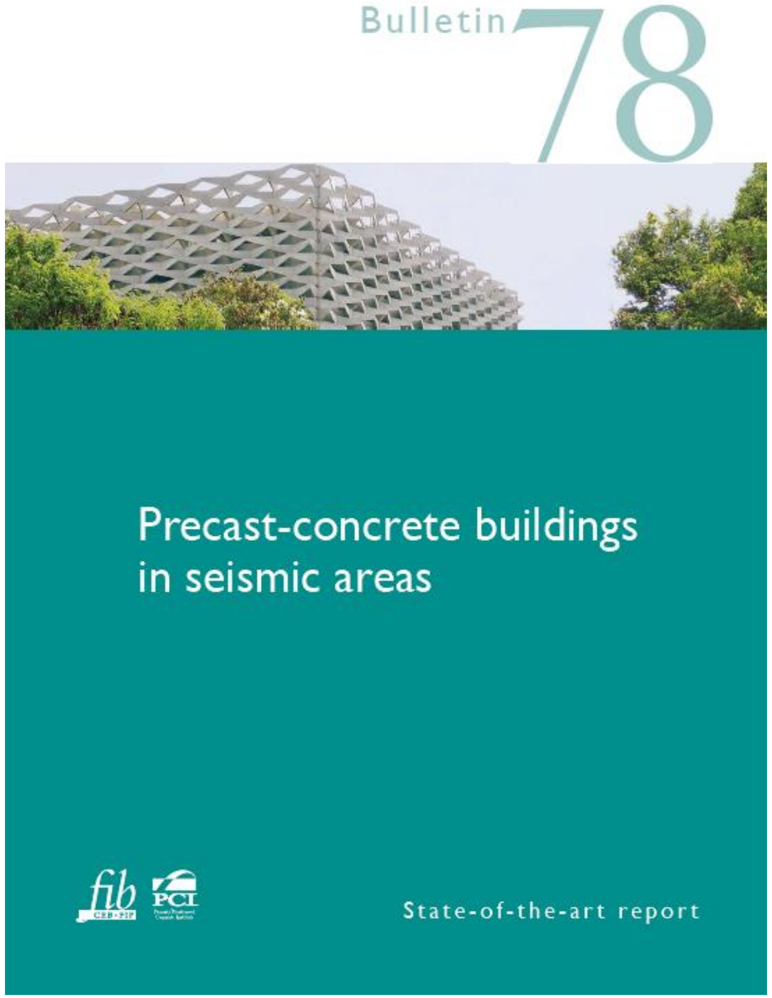

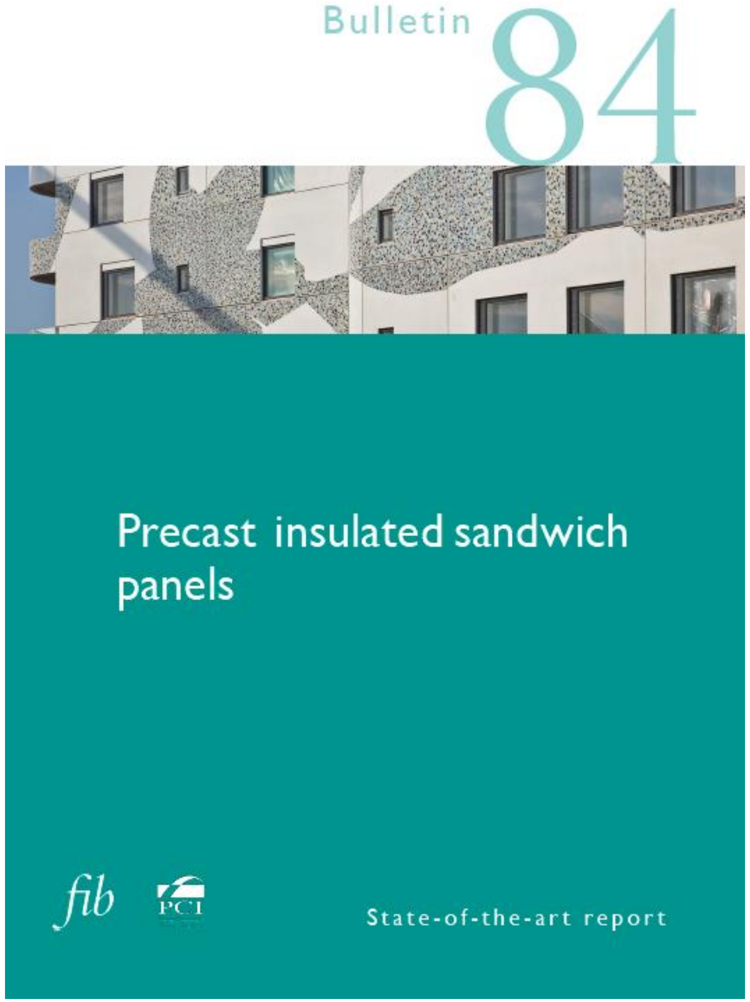

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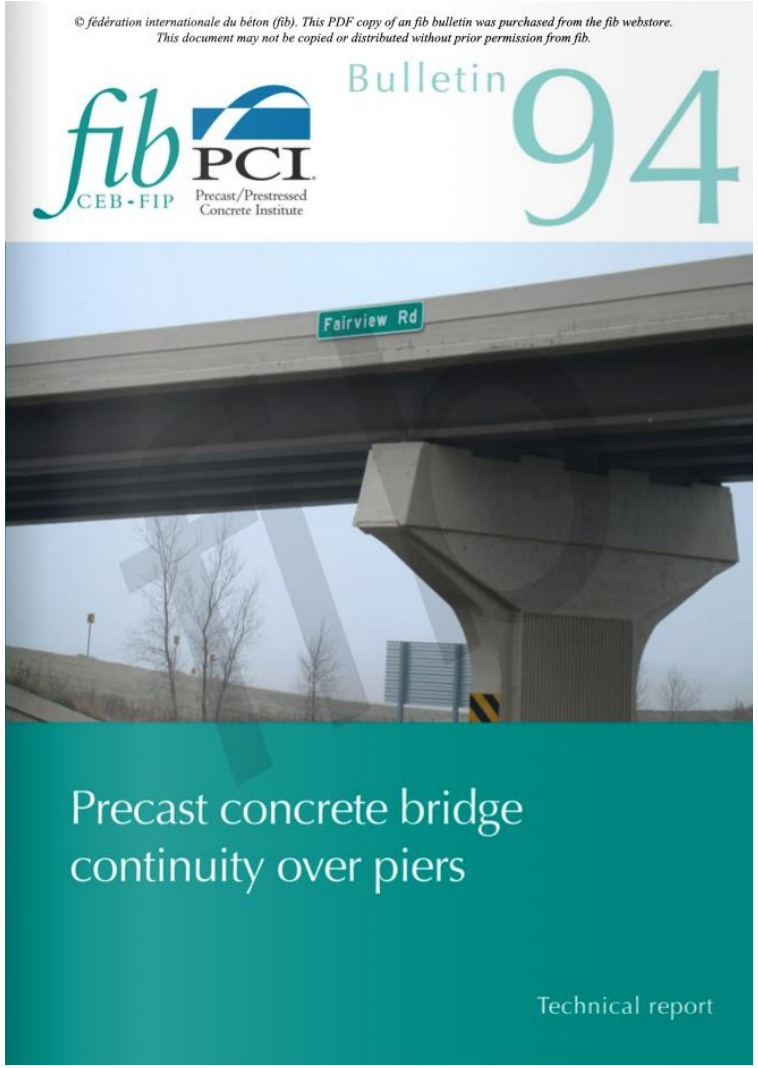

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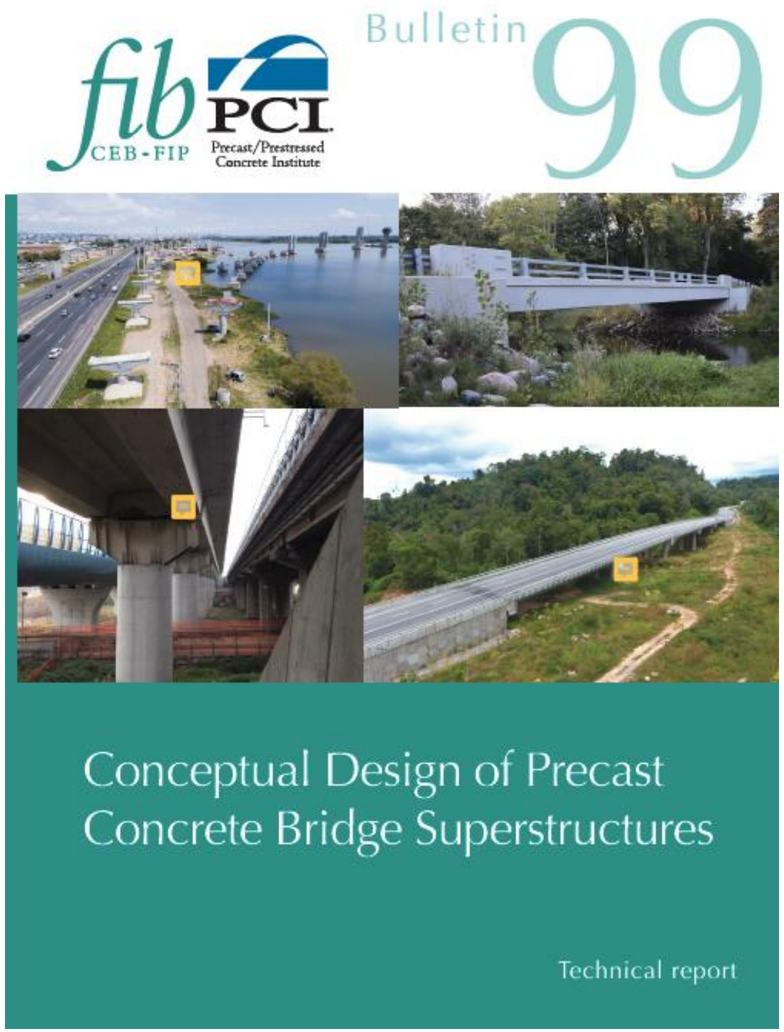
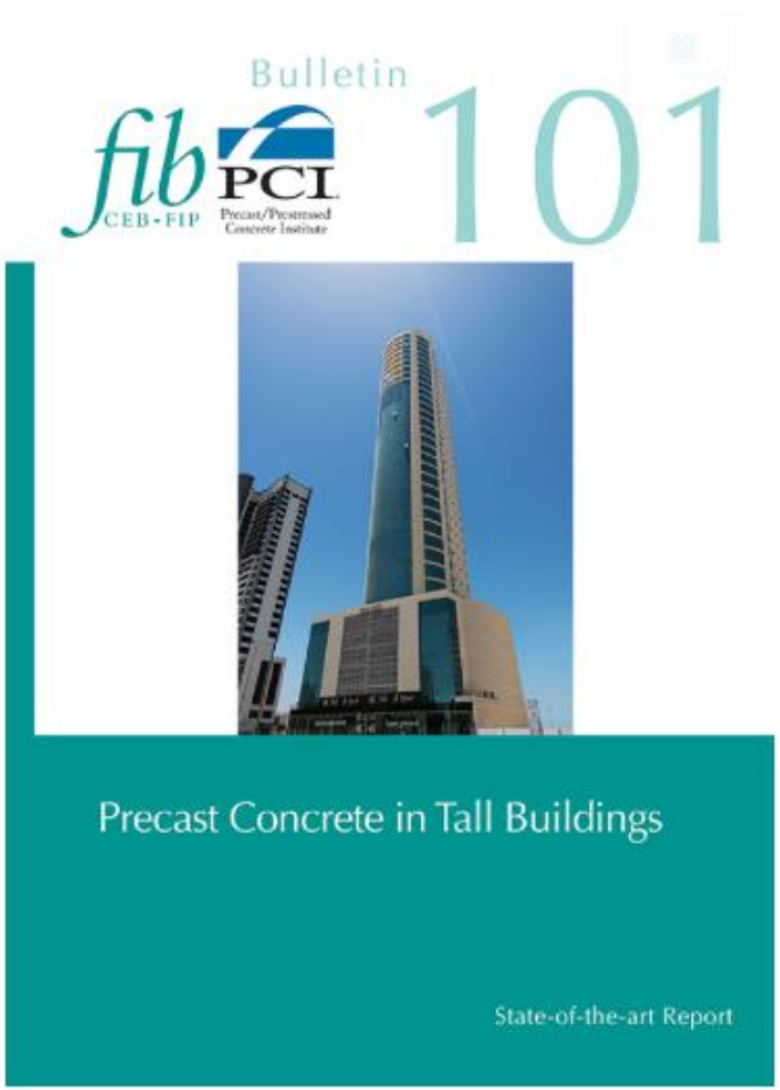
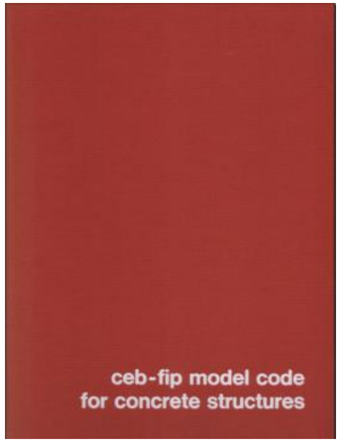
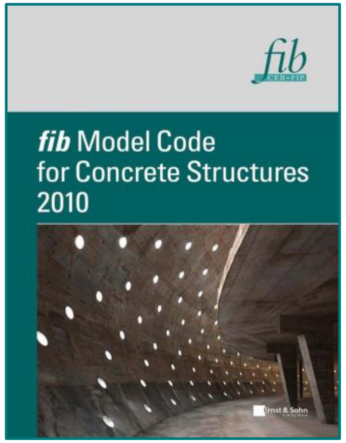




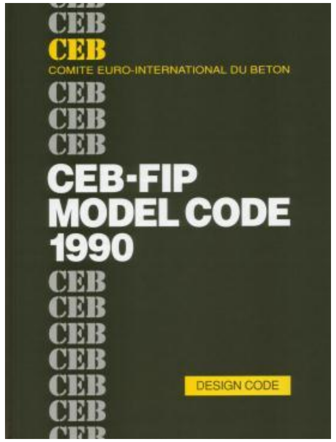
Evolution of Model Codes



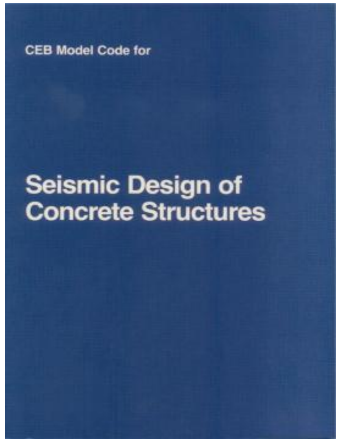
Model Code 1978



Model Code 2010



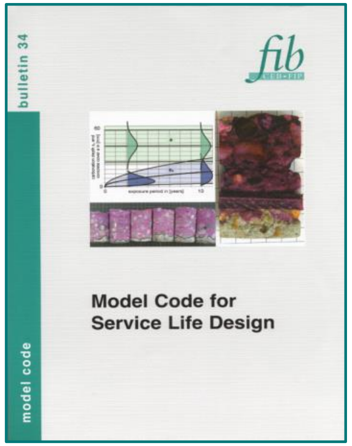
Model Code 1990



CEB Bull. 165 Seismic Design

New initiative

Model Code
(2020)



fib Bull. 34 Service Life Design

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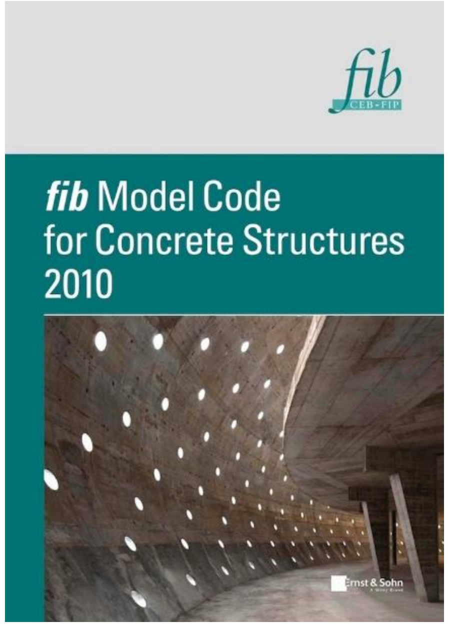
fib Model Code 2010



MC2010

5 Parts

10 Chapters

fib Model Code 2020

Greatly extended technical scope and coverage

MC2020

10 Parts

39 Chapters

MC2020

Identified overarching goals for the publication

- MC2020 is a single, merged structural code for new *and* existing structures
- Is an operational model code and oriented towards practical needs
- Includes worldwide knowledge with respect to materials and structural behaviour
- Recognizes the needs of engineering communities around the world

MC2020 Content

- Takes an integrated life cycle perspective
- Provides a holistic treatment of structural safety, serviceability, durability and sustainability
- Defines fundamental principles and a safety philosophy based on reliability concepts and sustainability
- Uses performance-based concept to remove specific constraints for novel types of concrete and reinforcing materials

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the *fib* Statement on Sustainability (2021)

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fib CEB-FIP

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DOI: 10.1002/suco.202100396

fib CEB-FIP WILEY

POSITION PAPER

The *fib* official statement on sustainability

Akio Kasuga

fib. The International Federation for Structural Concrete, Lausanne, Switzerland

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POSITION PAPER

fib WILEY

The *fib* official statement on sustainability

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Sustainability is a key value for today's society and also for the *fib*. In this sense, the whole organization is focused to develop information, documents, and tools to be used by the construction community and the society in general to achieve sustainability goals.

The ambition of the *fib* is that the work developed by the organization creates relevant knowledge in the three pillars of sustainability for the society. The work in the *fib* on the three pillars of sustainability is linked to the United Nations 17 Sustainable Development Goals and the developments of other organizations.

The *fib* is a not-for-profit association formed by 41 national member groups and approximately 1,000 corporate and individual members. The *fib*'s mission is to develop at an international level the study of scientific and practical knowledge capable of advancing the technical, social, economic, and environmental performance of concrete structures.

The knowledge developed and shared by the *fib* (*fib* Model Codes, *fib* Bulletins, *fib* events, *fib* workshops, *fib* courses, etc.) is entirely the result of the volunteering work provided by the *fib* members.

The *fib* was created in 1998 by the merger of the Euro-International Committee for Concrete (the CEB) and the International Federation for Pre-stressing (the FIP). These predecessor organizations existed independently since 1953 and 1952, respectively.

The *fib* is an independent society of professionals working in the field of concrete that includes concrete users, researchers, designers, and engineers from academia, design firms, constructors, and owners.

The *fib* has had a commission dedicated to environmental aspects of structural concrete from the start. Since then, the *fib* has created a Special Activity Group (SAG8) to deal with sustainability and environment in 2010 and created the Commission 7 "Sustainability" in 2015. In the *fib*, there are many Task Groups working on sustainability topics related to structural concepts, resilient structures, precasting, environmentally friendly concrete materials, recycling of materials and components, environmental product declarations, life cycle perspective analysis, etc. And *fib* will introduce some indicators to assess our commission activities in the field of sustainability. These indicators are used for the *fib* value assessment.

Sustainability concepts were already introduced in the Model Code 2010 and are a key part in the elaboration of the Model Code 2020 development. The *fib* Model Code is the only code which has sustainability philosophy as the main concept for the design, construction, and conservation of concrete structures built with concrete which started with MC2010.

Sustainability is a crucial concept for the design, construction, conservation and reuse of concrete structures. The *fib* has had a very intense activity on the environment and sustainability. As an example, we list the past bulletins developed in the *fib* about environmental aspects and sustainability:

- *fib* Bulletin 18. Recycling of offshore concrete structures. 2002.
- *fib* Bulletin 21. Environmental issues in prefabrication. 2003.
- *fib* Bulletin 23. Environmental effects of concrete. 2003.

Discussion on this paper must be submitted within two months of the print publication. The discussion will then be published in print, along with the authors' closure, if any, approximately nine months after the print publication.

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Sustainability in the Model Code

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ARTICLE

Sustainability perspective in *fib* MC2020: Contribution of concrete structures to sustainability

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ARTICLE

Sustainability perspective in *fib* MC2020: Contribution of concrete structures to sustainability

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Abstract

Sustainability is a global goal of sustainable development aimed at ensuring a quality life on the Earth for the future generations. Buildings, infrastructure and the entire built environment should be better prepared for the new conditions—they should be sustainable, resilient and adaptable to new situations. This requires new technical solutions for the construction, reconstruction, and modernization of buildings and all other engineering structures. Concrete is gradually becoming a building material with great potential for realizing technical solutions that meet new requirements, leading to the necessary reduction of environmental impacts and consequent improvement of social and economic conditions. The paper presents implementation of sustainability principles in the new fib Model Code 2020 (MC2020). This represents a contribution of the International Federation for Structural Concrete (fib) to the achievements of the Sustainable Development Goals (SDGs), set by the United Nations in 2015 as an action plan for the period up to 2030.

KEYWORDS
concrete, LCA, sustainability

1 | INTRODUCTION

1.1 | Global situation

The world faces an increasing number of environmental damage and/or natural disasters, and constantly growing economic and social problems and challenges. The most critical causes of this situation are population growth and global warming due to the rapidly increasing amount of greenhouse gasses in the atmosphere during last 2 hundred years.

In 2022, the world population has exceeded 8 billion. This represents 3.2× increase since 1950. During the same period, CO_2 emissions increased more than six times, world average temperature increased by 1°C and the number of recorded natural disasters increased 15 times.[1] Entire society, all nations, must take an action to slow down this process and adapt to the new natural and social conditions. To achieve these goals, it is crucial to implement sustainability and resilience as the most important objectives in all human activities and actions.

Discussion on this paper must be submitted within two months of the print publication. The discussion will then be published in print, along with the authors' closure, if any, approximately nine months after the print publication.

Structural Concrete. 2023;1–10. wileyonlinelibrary.com/journal/suco 1

MC2020. Specific aspects of Sustainability

Chapters related to Sustainability in the MC2020

- Chapter 3. Sustainability perspective
- Chapter 14. Concretes
- Chapter 26. Conceptual design
- Chapter 27. Approach to design
- Chapter 30. Evaluation of structural performance
- Chapter 31. Evaluation of other aspects of social performance
- Chapter 32. Evaluation of environmental performance
- Chapter 33. Evaluation of economic performance
- Chapter 34. Sustainability decision making

MC2020. Specific aspects of Sustainability

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3. Sustainability perspective

3.1 Principles of design and assessment with respect to sustainable development

3.2 Social performance

3.3 Environmental performance

3.4 Economic performance

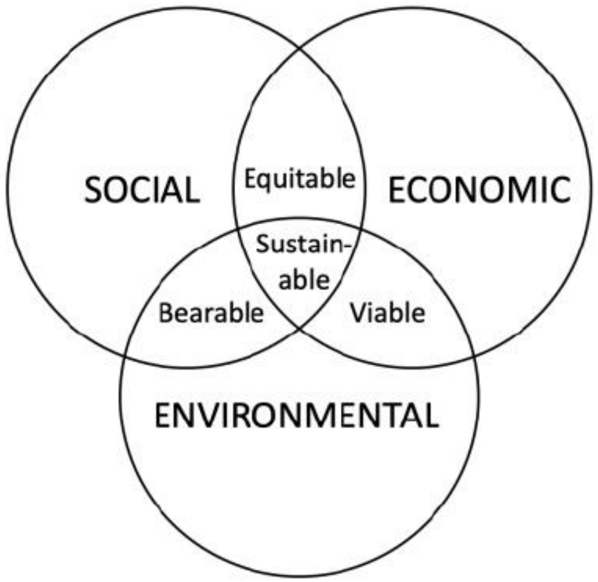


Figure 3.1-1: *Three pillars of sustainability and their interconnections*

3. Sustainability perspective

Sustainability is a global goal of sustainable development focusing to assurance of quality on the Earth for the future generations.

Concrete products and structures should, through their performance within the entire life cycle, contribute to sustainable growth of society and sustainable development of life on the earth by reducing negative impacts and increasing positive affect on the society, environment and economy.

Sustainability approach is a key conceptual principle to be considered through the life cycle of concrete structures in all activities, including design, production, construction, operation, maintenance, repair and dismantlement or circular use of any building or civil engineering work forming the built environment.

3. Sustainability perspective

In the design of new structures and in the assessment of existing structures, evaluation of performance should be performed for all three pillars of sustainability, …Social Performance,…Environmental Performance,… Economic Performance.

The approach to sustainability is consistent with the principles of performance-based design and assessment of concrete structures which is described in chapter 4. Hence, the relevant aspects of social, environmental an economic issues are to be dealt with as performances with the associated balanced requirements to be considered in order to provide the functions satisfactorily through the working life of the structure.

It is essential to consider changes and developments of performance within the entire life of a structure. Therefore, a life cycle approach is important in the sustainability evaluation. This consideration corresponds to the perspective of life-cycle management and care given in chapter 5.

MC2020. Specific aspects of Sustainability

3. Sustainability perspective

The relevant aspects of social, environmental and economic performance related to fulfilling performance requirements and contributing to achievement of sustainable development goals during the entire life of a structure shall be defined based on society and stakeholder needs.

They should be specified during briefing phase in the client brief and during the subsequent phases of the design and assessment process they should be dealt with in a way that is compatible with the decision process employed by the owner.

14. Concretes

14.5 Environmental performance of concrete

The evaluation of the environmental impact of a concrete structure is highly complex and comprises a great bandwidth of aspects reaching from emissions and resources consumption resulting from the production of the concrete and other building materials, the impact resulting from the building process itself, impacts resulting from the use of the structure (such as heating, cooling etc.) as well as impacts from the demolition of the structure.

Concrete, however, by definition, cannot be sustainable or non-sustainable in itself. It is rather in the responsibility of the designer to use the given material properties in the most sustainable manner during design, execution, and in-service operation of the structure throughout its entire life cycle.

26. Conceptual design

26.1.2 Consideration of sustainability

Sustainability is a holistic concept that involves many aspects that must be satisfied simultaneously and in a balanced way.

At the stage of conceptual design of new structures and interventions in existing structures the evaluation of sustainable performance shall be considered from the perspective of all three pillars of sustainability.

It is essential to consider changes and development of sustainable performance within the entire life of a structure.

26. Conceptual design

26.1.3 Consideration of life-cycle management

During the conceptual design stage, it is important to identify the different factors that may affect the service life of the structure, so that they may be included in the design basis; in addition, it is relevant to find solutions that may mitigate such factors in order to be integrated into the adopted solution.

26. Conceptual design

26.1.3 Consideration of life-cycle management

During the conceptual design stage, it is necessary to propose details that will minimize the deterioration of the structure. For example, early consideration of the necessary drainage details and their operation will help guide their development in later design stages.

In this phase, it is essential to identify which are the structural members that will have a shorter service life and the auxiliary means that must be provided for their replacement.

27. Approach to design

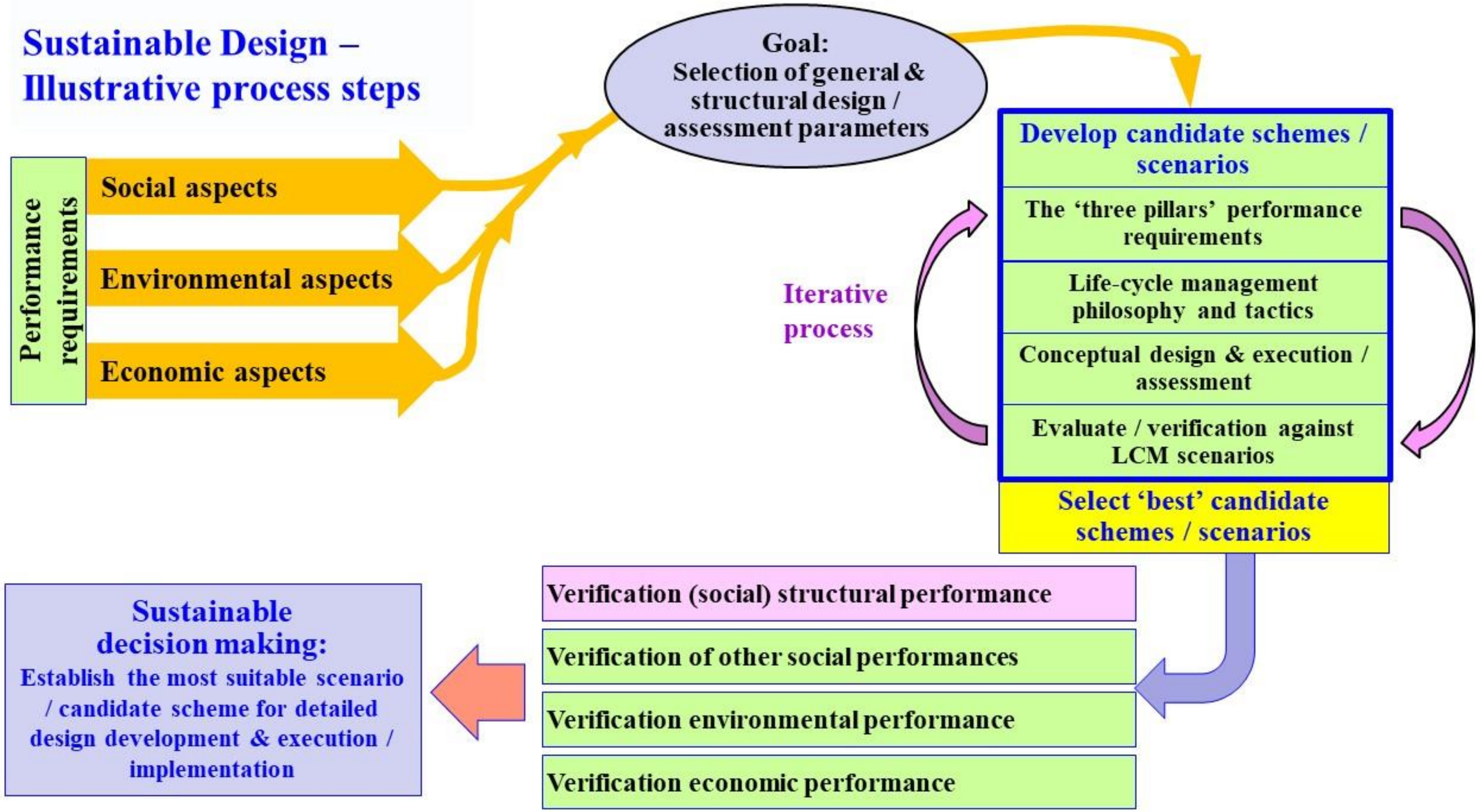
27.2 Consideration of sustainability

Sustainable development is an overarching objective of Model Code 2020 which is defined through three interdependent and mutually reinforcing pillars: namely the objectives and performance requirements established under the pillars of social responsibility, environmental quality and economic efficiency.

Figure 27.2-1 presents illustrative process steps for sustainable design, which are applicable to both general and structural design activities. Appropriately safe and reliable structural performance is a fundamental requirement for the satisfactory societal performance of a concrete structure.

MC2020. Specific aspects of Sustainability

27. Approach to design



MC2020. Specific aspects of Sustainability

31. Evaluation of other aspects of social performance

- 31.1 Introduction
- 31.2 Health and quality of the built environment
- 31.3 Safety and security
- 31.4 Aesthetics and cultural heritage
- 31.5 Impact on local community

31. Evaluation of other aspects of social performance

31.1 Introduction

The goal of including this requirement consists of taking into account the satisfaction perceived for all those stakeholders involved from the construction phase to the service life of the structure. Better understanding of the connections between civil engineering and society can help to minimise their negative impacts and help to develop more socially sustainable structures

31. Evaluation of other aspects of social performance

31.1 Introduction

The social issues include, on the one hand, criteria linked with the social effects of construction and operation of structure (protection of cultural heritage, service quality improve, local unemployment decrease, availability of affordable dwelling),

and on the other hand criteria regarding health, safety and comfort of occupants and workers on site.

MC2020. Specific aspects of Sustainability

31. Evaluation of other aspects of social performance

31.2 Health and quality of the built environment

Health and quality of built environment has a fundamental impact on how people perceive, function, and behave. It makes a direct contribution to community social live and should be considered within all live cycle stages from design, construction, operation to the end of life of structure.

Concrete and concrete structures could positively contribute to specific aspects of social performance by following qualities:

- Acoustic comfort
- Thermal comfort
- Maintainability
- Flexibility
- Healthiness

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31. Evaluation of other aspects of social performance

31.3 Safety and security

Security performance evaluation could be based on a risk analysis, where security risk could be generally expressed as a function of threats, vulnerabilities and potential impacts or expected loss. Nevertheless, application of risk analysis to the real problem is difficult due to a lack of relevant and meaningful variable data (e.g., cost of vulnerability, etc.).

31. Evaluation of other aspects of social performance

31.4 Aesthetics and cultural heritage

The evaluation of aesthetics is in general influenced by the subjective taste of individuals. It is usually a part of evaluation of jury within engineering and architectural competition.

Cultural heritage includes, inter alia, tangible culture such as buildings and other construction monuments. Protection and conservation of historical buildings and other constructions represent an essential and highly important part of preservation of cultural human history.

MC2020. Specific aspects of Sustainability

31. Evaluation of other aspects of social performance

31.5 Impact on local community

Negative impacts:

- Interferences associated to noise and particles pollution;
- Traffic disturbances during construction;
- Soil erosion impacts due to construction, including impacts to ground water level;
- Increased demand for water during construction and potential impact to water quality;
- Time delays or loss of activity due to maintenance, rehabilitation, repair activities.

Positive impacts:

- New construction can create economic advantages for the local community, incl. increase employment during construction and employment after start of new built infrastructure;
- Improving transportation networks provides economic benefits to local community properties. By reducing travel time, people in local communities can reduce fuel costs and vehicle depreciation;
- Increased attractivity of the area by improvement of infrastructure.

32. Evaluation of environmental performance

32.1 General

32.2 Objectives of evaluation of environmental performance

32.3 Principles of environmental impact evaluation

32.4 Life cycle assessment

32.5 Environmental Product Declaration

32.6 EIA – Environmental Impact Assessment

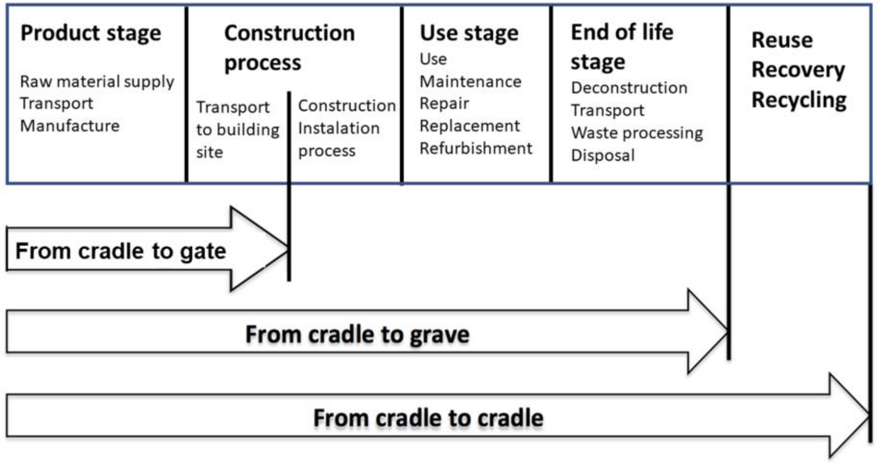

Figure 32.3-2: Different concepts of LCA of concrete structures.

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32. Evaluation of environmental performance

32.1 General

The goal and scope of environmental impact evaluation shall be consistent with the intended application in the design, construction and operation processes of concrete structure. The evaluation and optimization model should be sufficiently well defined to ensure that the results of the study are compatible, relevant and sufficient to address the pre-defined goals.

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32. Evaluation of environmental performance

32.2 Objectives of evaluation of environmental performance

Due to the global character of the problem and complexity of relations among the elements of the analysed system, environmental performance evaluation requires consideration of its multicriterial character. The use of multicriteria evaluation methodology and multicriteria optimization techniques respecting the significance of the system's interrelationships is thus essential and necessary.

The evaluation method should be capable to cover all relevant flows of material, energy and others, and should consider corresponding essential environmental criteria. However, simplification of the model is usually admitted.

MC2020. Specific aspects of Sustainability

32. Evaluation of environmental performance

32.3 Principles of environmental impact evaluation

The total environmental impact of product (i.e. concrete structure) should be considered throughout its whole life, from raw material acquisition, through production, use and disposal.

It is essential that the goal of optimization efforts should be to keep structural materials in the closed material cycle (the grey area) as long as possible. The high importance of maintenance and repair processes, which can increase the durability of concrete structure, is thus evident. Equally, the significance of renovation and recycling phases on the total environmental impact of concrete structure is considerable.

Life cycle approach allows for the choice of either a cradle-to-gate, cradle-to-grave or cradle-to-cradle life cycle.

32. Evaluation of environmental performance

32.3 Principles of environmental impact evaluation

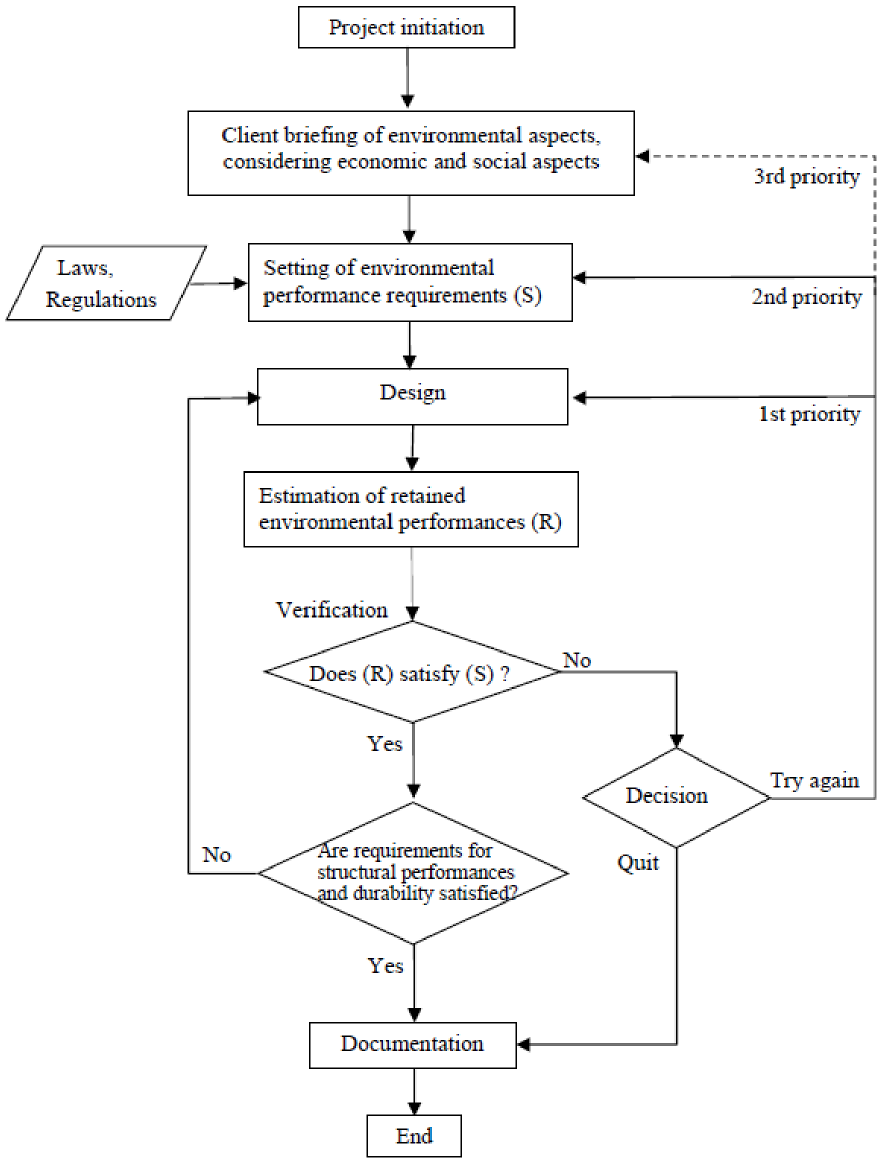

Figure 32.3-3: Procedure for environmental design of concrete structures according to ISO 13315-4 [32-2]

32. Evaluation of environmental performance

32.4 Life cycle assessment

The evaluation of the environmental performance is performed using standard Life-cycle assessment (LCA) methodology. This methodology is defined in a set of ISO, CEN, ACI and other standards. This chapter presents basic principles of LCA.

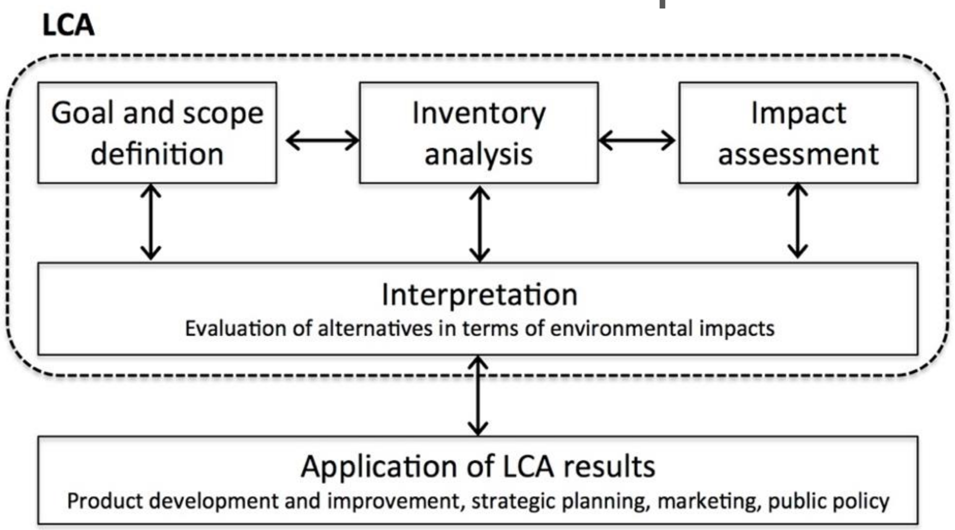

Figure 32.4-1: Relationships and interactions of the steps in a LCA, fib Bulletin 71 [32-1].

32. Evaluation of environmental performance

32.5 Environmental Product Declaration

ISO 21930 [32-11] provides core product category rules (PCR) for all construction products and services including concrete components and related services. In accordance with ISO 21930 [32-11], ISO 13315-8 [32-12] provides principles, procedures and requirements for environmental labels and declaration for concrete and concrete structures specifically. This standard provides rules to ensure that all

Environmental Product Declarations (EPD) of construction products, services and processes are derived, verified and presented in a harmonised way. The overall goal of an EPD is to provide relevant, verified and comparable information about the environmental impact from construction products (e.g. concrete component like precast floor panel, precast column, etc.) and services.

32. Evaluation of environmental performance

32.6 EIA – Environmental Impact Assessment

Environmental Assessment is according to European legislation (https://ec.europa.eu) a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made.

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33. Evaluation of economic performance

33.1 Introduction

33.2 Cost categories

33.3 Methodology of LCCA

$$C_{T_d}(\boldsymbol{p}) = C_0(\boldsymbol{p}) + \sum_{n=1}^{N(t_D)} C_{m,n}(\boldsymbol{p})\delta(t_n) + C_D\delta(t_D) \qquad (33.2\text{-}2)$$

where:

C_0	Design and construction costs (monetary unit);
$C_{m,n}$	Cost of the n^{th} preventive maintenance (monetary unit);
C_D	End-of-service-life costs –Decommissioning costs-(monetary unit);
$\delta(t)$	Discounting function;
t_n	time at which the n-th intervention occurs;
$N(t_D)$	the total number of interventions within time frame t_D;
t_D	end of service life of the system;
$\boldsymbol{p}$	vector parameter of system properties.

33. Evaluation of economic performance

33.1 Introduction

The evaluation of the economic performance is normally done through a Life-Cycle Cost Analysis (LCCA)

LCCA is an approach for the assessment of the financial feasibility of projects. It is frequently based on Discount Cash flow analysis, which is commonly limited to Net Present Value analysis; however, other approaches can be used (e.g., real options).

Cost and risk are interdependent. Both should, in all cases, be considered together. Sometimes, the most economical solution from the point of view of the cost could also be that with the higher risk associated.

33. Evaluation of economic performance

33.2 Cost categories

The two main cost categories are:

i. direct; and
   - design and construction costs,
   - overhead, risk and benefit of the construction and operation;
   - maintenance, inspection and operation costs, and
   - end of service life costs.

ii. indirect costs.

   Indirect costs are those which society incurs as a result of the construction, operation, interventions or decommissioning of the project.

33. Evaluation of economic performance

33.3 Methodology of LCCA

Despite the differences among existing LCC methodologies, the following steps can be identified as general in any method of LCC analysis:

- Definition of the project objective and scope;
- Establishing minimum performance requirements and restrictions;
- Identification of alternative options;
- Assumptions and parameters;
- Definition of the LCC model;
- Cost and time database;
- LCC Evaluation;
- LCC results and interpretation: identification of key cost drivers;
- LCC Sensitivity, uncertainty and risk analysis.

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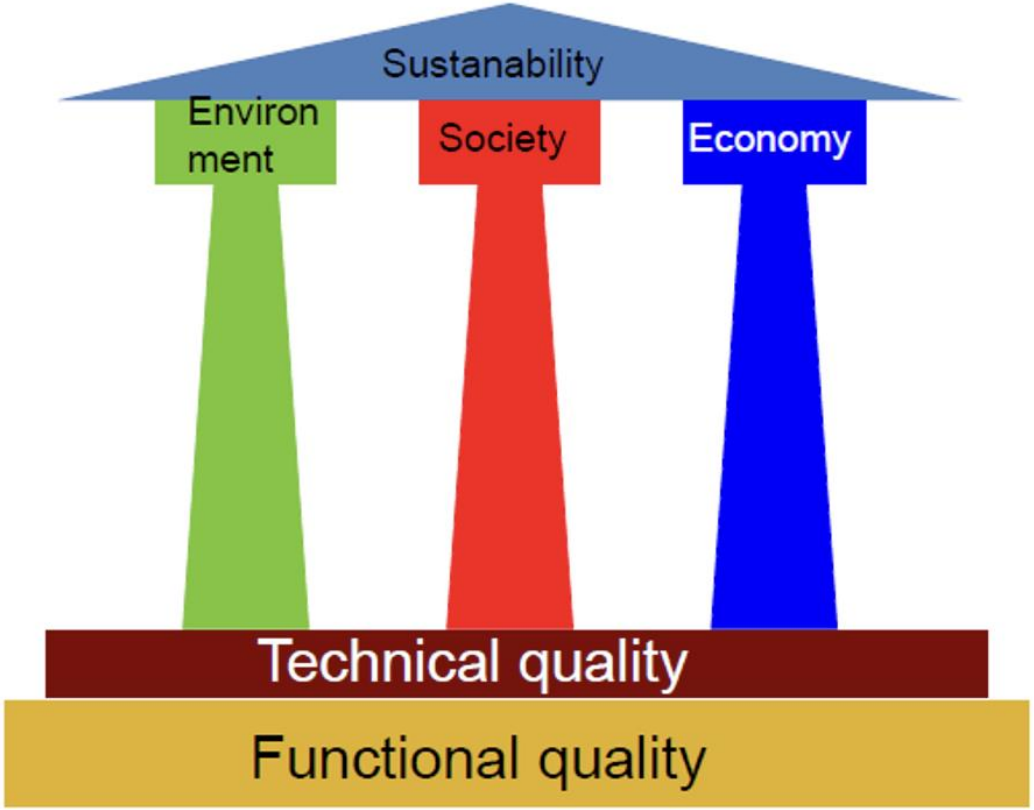
34. Sustainability decision making

- 33.1 Introduction
- 33.2 Evaluation



34. Sustainability decision making

33.1 Introduction

Each one of the pillars measures a different aspect of sustainability and the criteria and indicators that compose these pillars are generally not combinable. Therefore it is not possible to combine them in a direct way.

Administrations normally have economic limitations but also value specific aspects or ambitions of the project. Normally they will give more preference to solutions that add more value to their requirements if they are in the economic range that is affordable to them. Administrations can be restricted by economic limitations but these should value other requirements and ambitions of the project by properly considering the other pillars.

34. Sustainability decision making

33.2 Evaluation

There are several available approaches oriented to assess sustainability by combining the three pillars. Some of these tools might dismiss the explicit consideration of the ISO regulations for the evaluation of the performance according to the three pillars.

Should the pillars be combined to derive a global sustainability that permits to make decisions, a transparent and consistent procedure has to be followed to establish objective performance for each of the three pillars and the combination of them.

Sustainability-related Task Groups in the *fib*

SPECIAL ACTIVITY GROUP SUSTAINABILITY

- TG.SAG.1 Data bases
- TG.SAG.2 Low carbon concrete structures and best practices

COMMISSION 7 SUSTAINABILITY

- TG 7.1 Sustainable concrete- general framework
- TG 7.3 Concrete with recycled materials
- TG 7.5 Environmental product declarations
- TG 7.6 Resilient structures
- TG 7.7 Sustainable concrete masonry components and structures
- TG 7.8 Waste materials and industrial by products for high performance reinforced concrete structures

OTHER GROUPS RELATED TO SUSTAINABILITY

- TG 1.5 Structural sustainability
- TG 4.8 Low-carbon concrete structures
- TG 6.3 Sustainability of precast structures

Special Activity Group (SAG). Sustainability

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Chair: Domenico Asprone (Italy)

Scope:

The In 2020, many countries, including the EU and Japan, declared their commitment to carbon neutrality by 2050. This movement has gained momentum, particularly after the COVID-19 pandemic, with over 100 countries now involved. Despite the significant CO_2 emissions of the concrete sector, concrete remains an essential material for human prosperity. To achieve sustainability goals, the world will require concrete structures with minimal CO_2 emissions in the near future.

Clients and taxpayers may begin to demand that designers, constructors, and owners quantify the CO_2 emissions of their projects properly. In this context, the *fib* must be prepared to lead the change in the structural concrete community. It is essential that the *fib* shares its knowledge and provides proper methodological approaches to enable a reliable assessment of the environmental impact of concrete structures.

Special Activity Group (SAG). Sustainability

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To achieve its goal, the SAG will focus on three objectives:

- Establishing a comprehensive database of environmental impact data for structural materials used in concrete structures. The SAG will prioritize data related to the construction stage, but will also develop a strategy to manage data from the operational and maintenance stages, as well as the dismission stage. The data platform will need to be continuously maintained by collecting new data and updating existing data, with a focus on different lifecycle stages in different geographical areas. The SAG will source this data from manufacturers, designers, associations, and other institutions.
- Defining a reliable methodological approach to support designers in quantifying the environmental impact of concrete structure projects. The methodology will be based on LCA principles and focus on the requirements and performance of structures. The approach will be easily implementable and usable in the design process, with a common set of indicators and proper metrics established to compare data and allow for the definition of benchmarks. The methodology may also identify a Product Category Rule, according to the ISO 14000 series, to enable designers to produce EPDs for individual concrete structures.
- Identifying the best tools and knowledge to guide the decision-making process towards optimal structural solutions in terms of environmental impact while still satisfying expected structural and functional performances. The SAG will suggest proper optimization strategies and procedures and identify best practices for different structures, in various market conditions and geographical areas.

Special Activity Group (SAG). Sustainability

Objective 1: *fib* Database (TG.SAG.1, Costantino Menna)

- Existing database at national or regional level: state-of-the-art and availability
- Main properties/needs of the *fib* Database (sql, no-sql, regional, LCA phases, time representativeness…)
- Source data (manufacturers, associations, literature, …)
- Tools to use the database (online platform, report, specific Bill of Quantity software, BIM, …)

Special Activity Group (SAG). Sustainability

Objective 2: *fib* methodology (TG.SAG.1, Costantino Menna)

- Existing methodologies and standards: PCR, ISO, …
- Main properties/needs of the *fib* methodology (regional, LCA phases, boundary system, inventory data, Impact categories…)
- Level of application (structural sytems, structural typologies, technological boundaries)
- Tools to use the methodology (online platform, report, specific Bill of Quantity software, BIM, …)
- Methodology certification/standardization (EPD, Model code…)
- Examples and case studies

Special Activity Group (SAG). Sustainability

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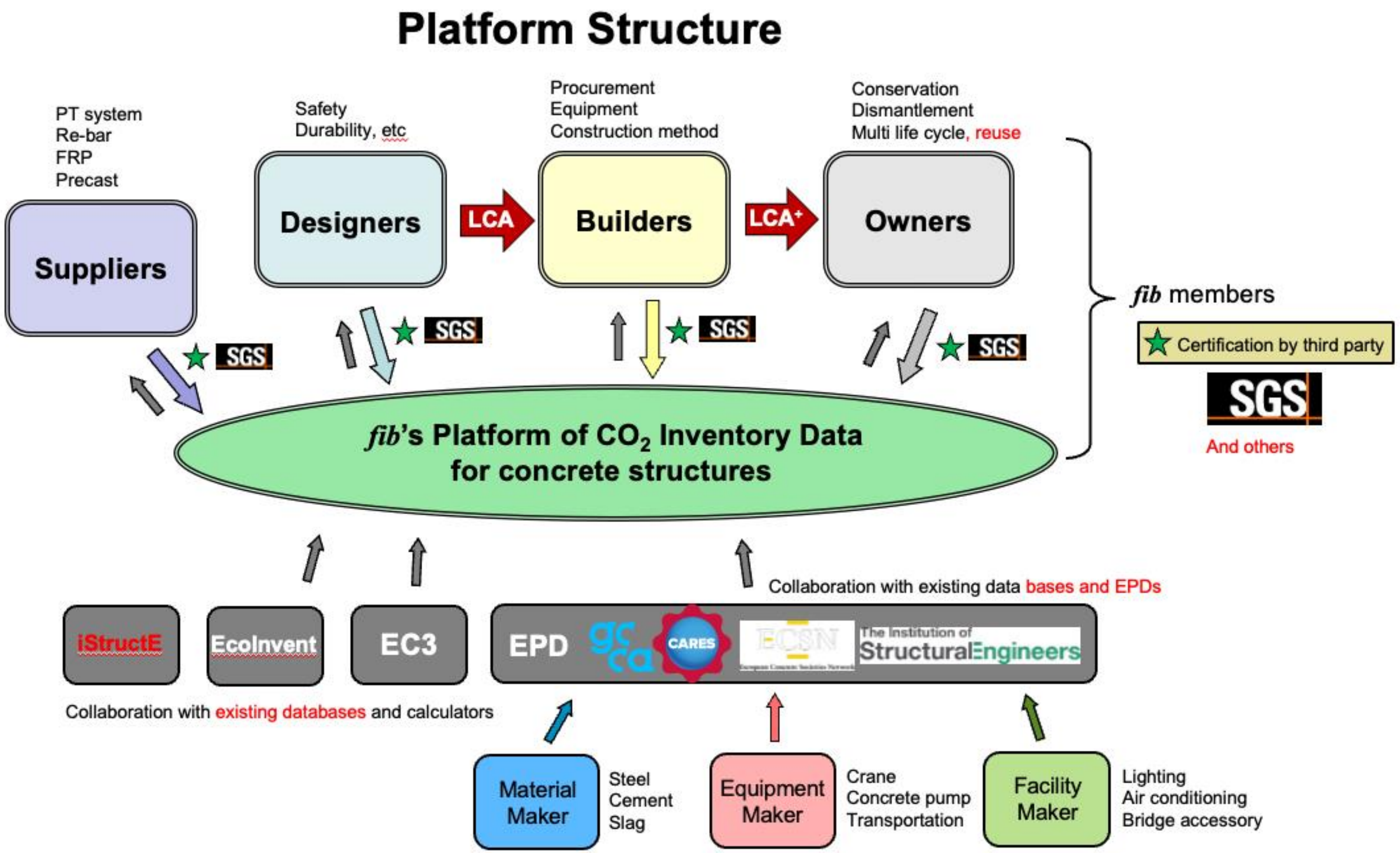
BUILDING LIFE CYCLE INFORMATION																additional information outside the system boundary
A PRODUCT STAGE			A CONSTRUCTION STAGE		B USE STAGE							C END OF LIFE STAGE				D POTENTIAL BENEFITS AND LOADS
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw Material Supply	Transport	Manufacturing	Transport	Construction - Installation process	Use; installed products	Maintenance	Repair	Replacement	Refurbishment	Operational Energy use	Optional Water use	Deconstruction	Transport	Waste processing for reuse, recovery or/ and recycling	Disposal	Reuse - Recovery - Recycling - potential

Special Activity Group (SAG). Sustainability



Special Activity Group (SAG). Sustainability

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Objective 3.1: Low carbon concrete structures and best practices (TG.SAG.2, Agnieszka Bigaj):

- Identifying range of **material, structural and technological innovation** to enhance sustainability of concrete structures
  - innovations at material level, structural design level, construction level, maintenance and interventions level, dismantlement and circular use:
    - addressed in ongoing *fib* activities
    - not yet addressed in ongoing *fib* activities
- Identifying **best practices for different innovative solutions**, for various structures, market conditions and geographical areas

Special Activity Group (SAG). Sustainability

Objective 3.2: Low carbon concrete structures and best practices (TG.SAG.2, Agnieszka Bigaj):

- Formulating consistent basis for **performance-based design of sustainable structures in a life cycle perspective** suitable for enhancing the sustainability of concrete structures:
  - consistent safety philosophy for structural design innovative solutions (reliability requirements and uncertainties treatment in verification of structural performance)
  - principles of equivalent performance approach for structural design with innovative (material) solutions
  - framework for performance evaluation based on material and structural testing of innovative solutions

Special Activity Group (SAG). Sustainability

Objective 3.3: Low carbon concrete structures and best practices (TG.SAG.2, Agnieszka Bigaj):

- Identifying methodologies for **decision-making process towards sustainable structural solutions for design, execution and life cycle management including interventions,** optimized in terms of environmental impact, economic and social performance, and satisfying structural and functional performance requirements:
  - optimization objectives
  - effective optimization strategies and procedures

Consideration about new developments

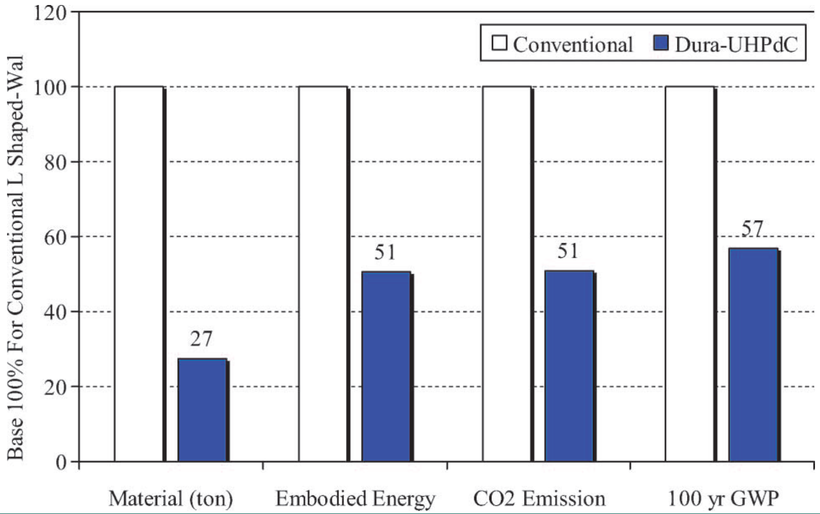
(Joost Walraven)

Criteria for sustainability?

No official limit state criteria like for structural safety, serviceability and durability.

Criteria for comparison between solutions:
- carbon footprint,
- embodied energy,
- energy conservation,
- efficient use of resources
- waste reduction
- global warming potential

Question: do we need limits or also more general considerations?



Special Activity Group (SAG). Sustainability

Limit values or design principles when pursuing sustainability? (Joost Walraven)

Pedestrian bridge in UHPC in Calgary 2007 (over 8 lanes);
Bridge length 53m,
Construction time 8 hours so no traffic congestions;
No intermediate support so safety and robustness.

Pedestrian bridge in Leyden in the Netherlands in CRC-concrete (Compact Reinforced Concrete) l = 38m, h = 0.275m. Architectural solution in historical city centre

Sustainability of buildings in relation to service life

(Joost Walraven)

Apartment building Vlaardingen, The Netherlands (1960)

1980: From small apartments with many small rooms to larger apartments with larger rooms

2020: Need for more small apartments for singles of small families

Globe Consensus

http://globe-consensus.com

Brasil:

Abraham Belk	TQS
Ricardo França	USP
Vanderley John	USP
Carlos Massucato	Ibracon

Globe Consensus

Benchmarking of Resource Use and Embodied CO_2 in Buildings

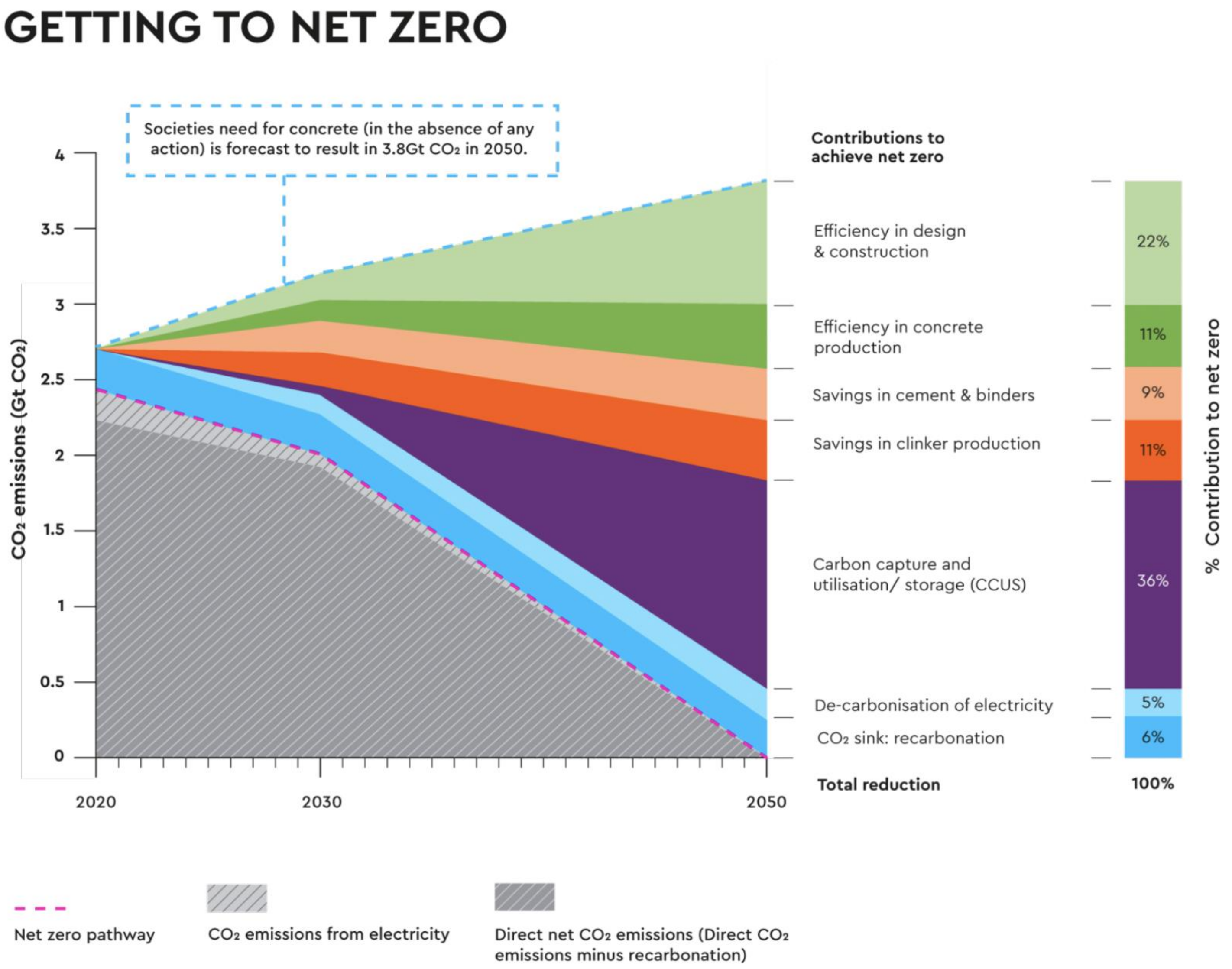
The objective is to set the foundation for global benchmarks on the carbon footprint of buildings, based on a joint methodology for assessing and reporting embodied impacts in an attempt to generate globally harmonized yet location-specific benchmarks. Measuring and benchmarking is a key strategy to reduce the resource use and CO2 footprints of the global building stock. A global standard will allow to compare and learn from the wide variety global design and construction practices, fostering research and innovation which are crucial to our common climate ambitions.

Globe Consensus

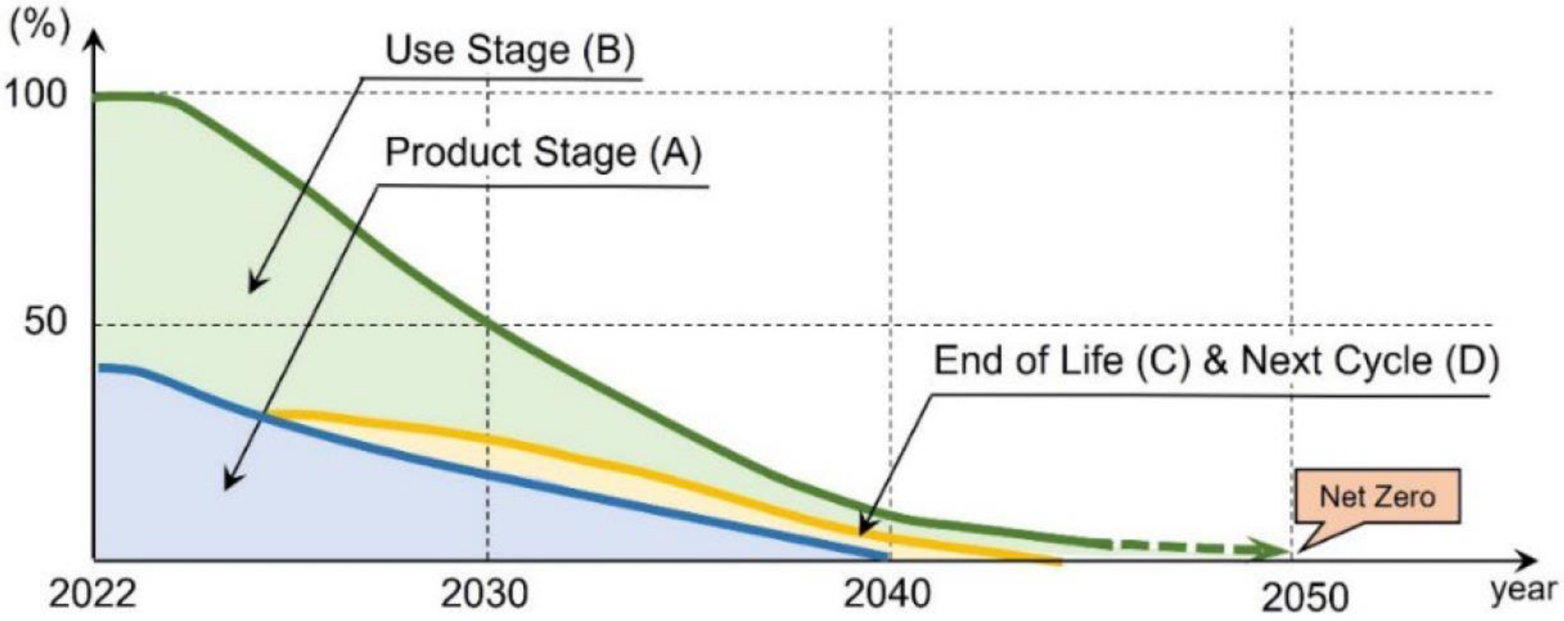
GLOBE Data protocol for quantifying embodied carbon emissions in load-bearing building structures – Prerequisites for unified global benchmarking of embodied CO_2 in buildings.

The paper at hand therefore establishes basic principles as how to carry out such a quantification, while considering different possible usage scenarios of the resulting data, such as political and regulatory, normative and stakeholder action. The provisions given in this paper are especially intended to generate a discussion within the normative community on how to implement embodied CO_2 in limit state considerations during the design process of load-bearing structures.

GCCA roadmap



fib Roadmap

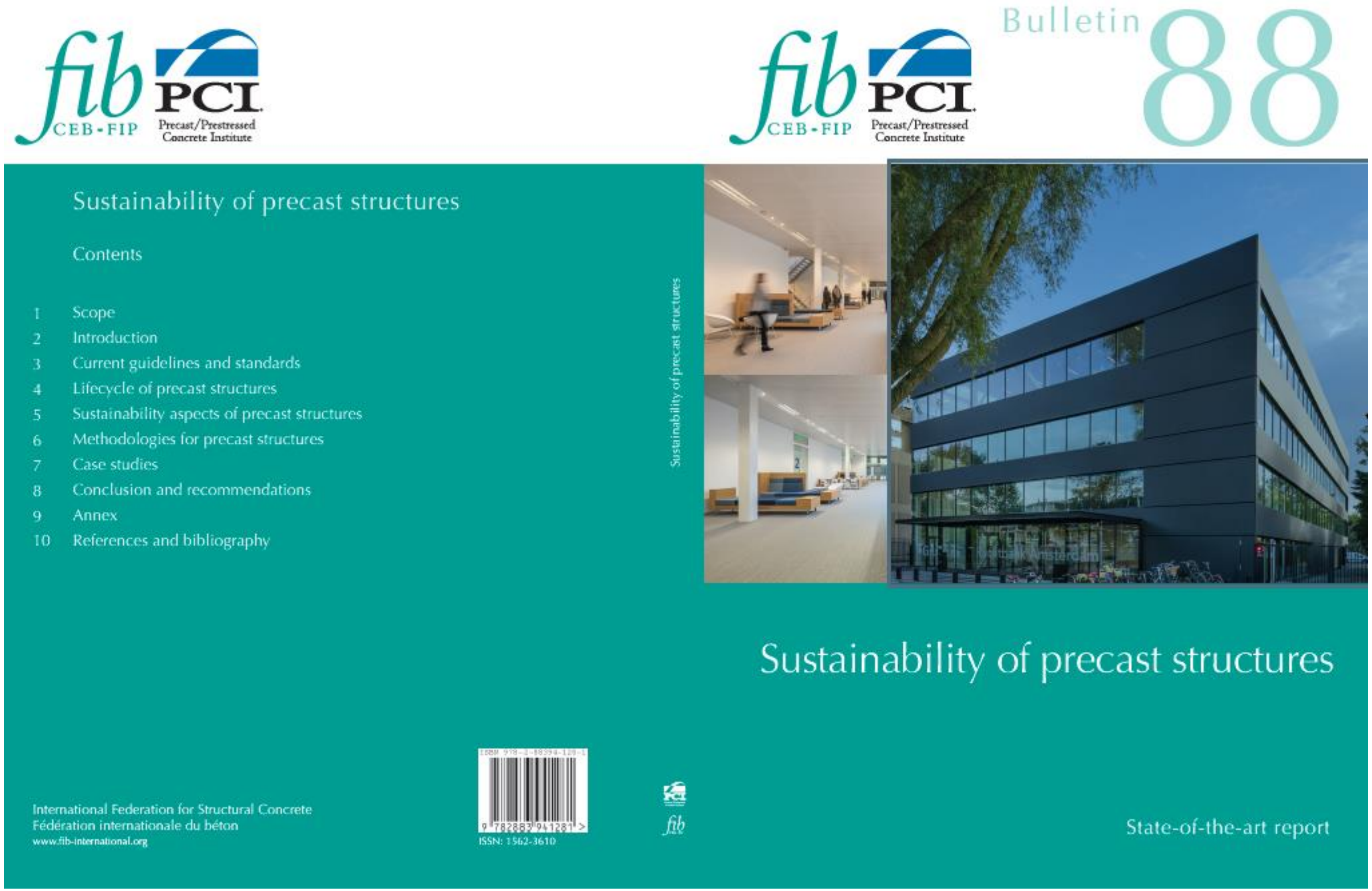


Stage	100	50	10	0 (%)
A	40	20	0	0
B	60	20	5	0
C&D		10	5	0

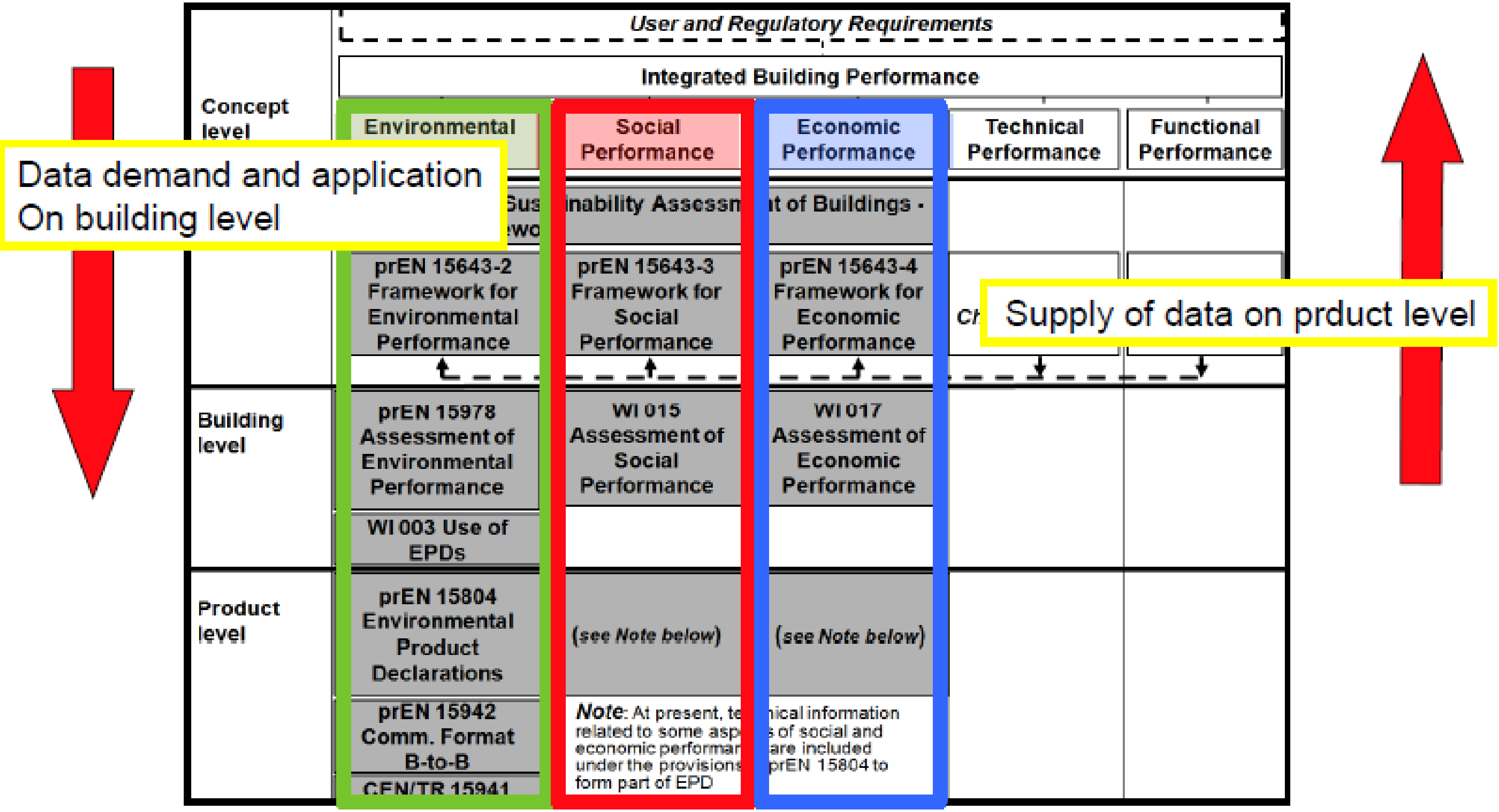
Fig. 1 Roadmap to carbon neutrality for fib members

TG 6.3 Sustainability of structures with precast elements

Conveners: De la Fuente, Josa, Fernández-Ordóñez (Spain)



Sustainability in Housing: CEN TC 350



Sustainability in Housing: CEN TC 350

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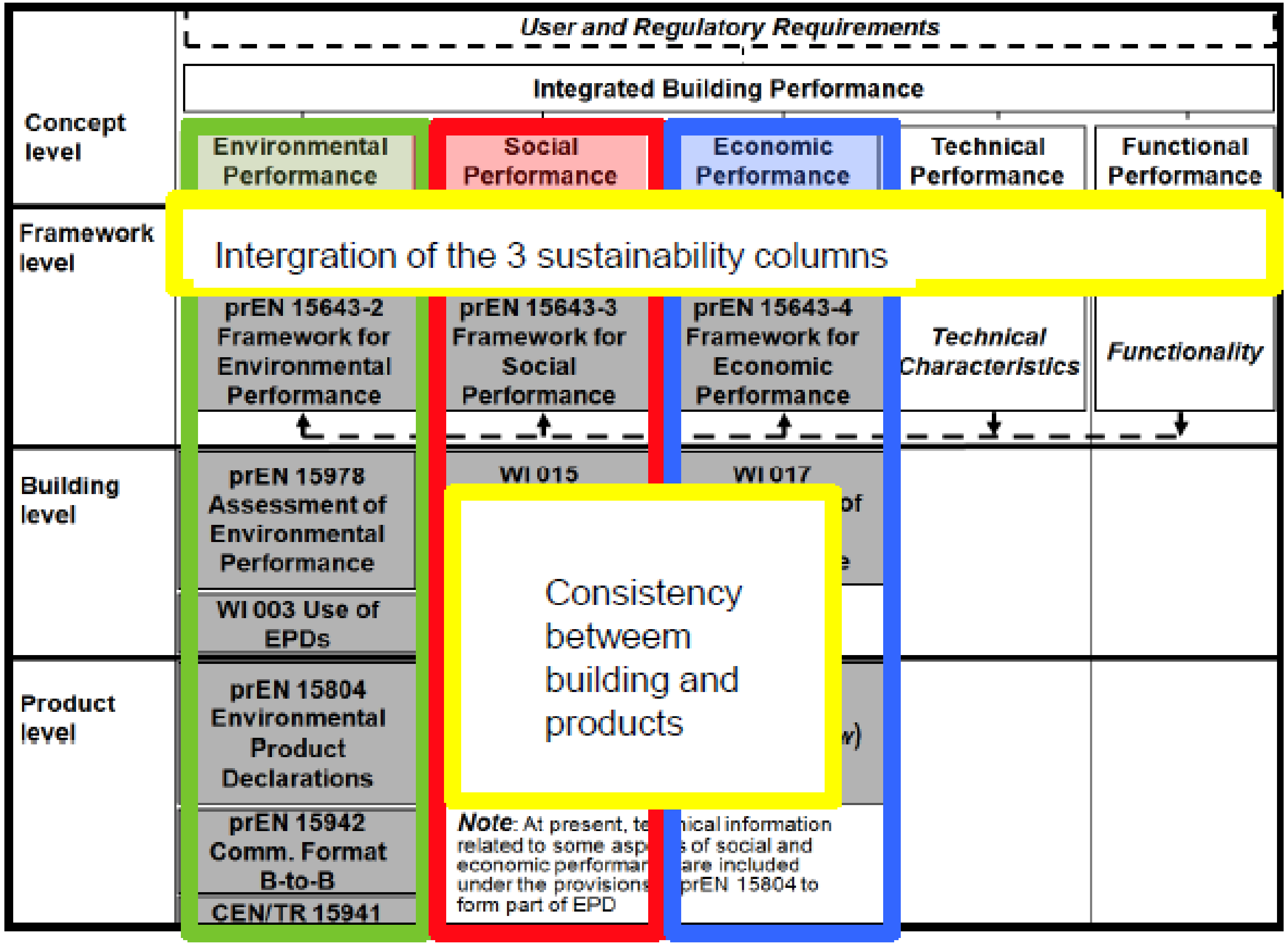

Sustainability in Housing: EPD

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fib CEB-FIP

Environmental Declaration ISO/DIS 14025 Type III

CONTIGA

Miljødekke

EPD

Næringslivets Stiftelse for Miljødeklarasjoner
NEPD nr.11N
Godkjent av Stiftelsens Verifikasjonskomité
Gyldig til 31.12.2005

Bjørn Svaen

Deklarasjonen er utarbeidet av
Stiftelsen Østfoldforskning

Miljødekke er produsert av:
Contiga AS
Kontaktperson: Jørn Injar
Telefon: 69 24 46 00
E-mail: jorn.injar@contiga.no
Organisasjons nummer: No 917 507 837
EMAS/ISO-14001 reg.No.: -/-

Produktspesifikasjon:

	Andel av total [%]	*Data quality*	*Masse [kg/m2 element]*
Sand	48,5	Stedsspesifikke data	192,3
Pukk	11,5	Stedsspesifikke data	45,6
Miljøpukk	20,4	Stedsspesifikke data	81,1
Sement	12,5	Stedsspesifikke data	49,4
Additiver	0,1	Under cut-off	0,5
Vann	1,8		7,0
Slamvann	3,9	Fra egen produksjon	15,4
Armering	1,3	Generelle data	5,2
Total			396,6

Bakgrunns informasjon:
Studien omfatter hele livsløpet.
Funksjonell enhet: 1m^2 hulldekkelement HD265, basert på element 12 m med 8 spenntau.
Årstall for studien: 2000
Datagrunnlag: Råvaredata fra 1998-01
Antatt levetid: 100 år
Produksjonssted: Contiga AS, Moss
Antatt markedsområde: Østlandsområdet.

Leverandørers miljøstyringssystem

- Contiga har for tiden ingen krav til leverandører om

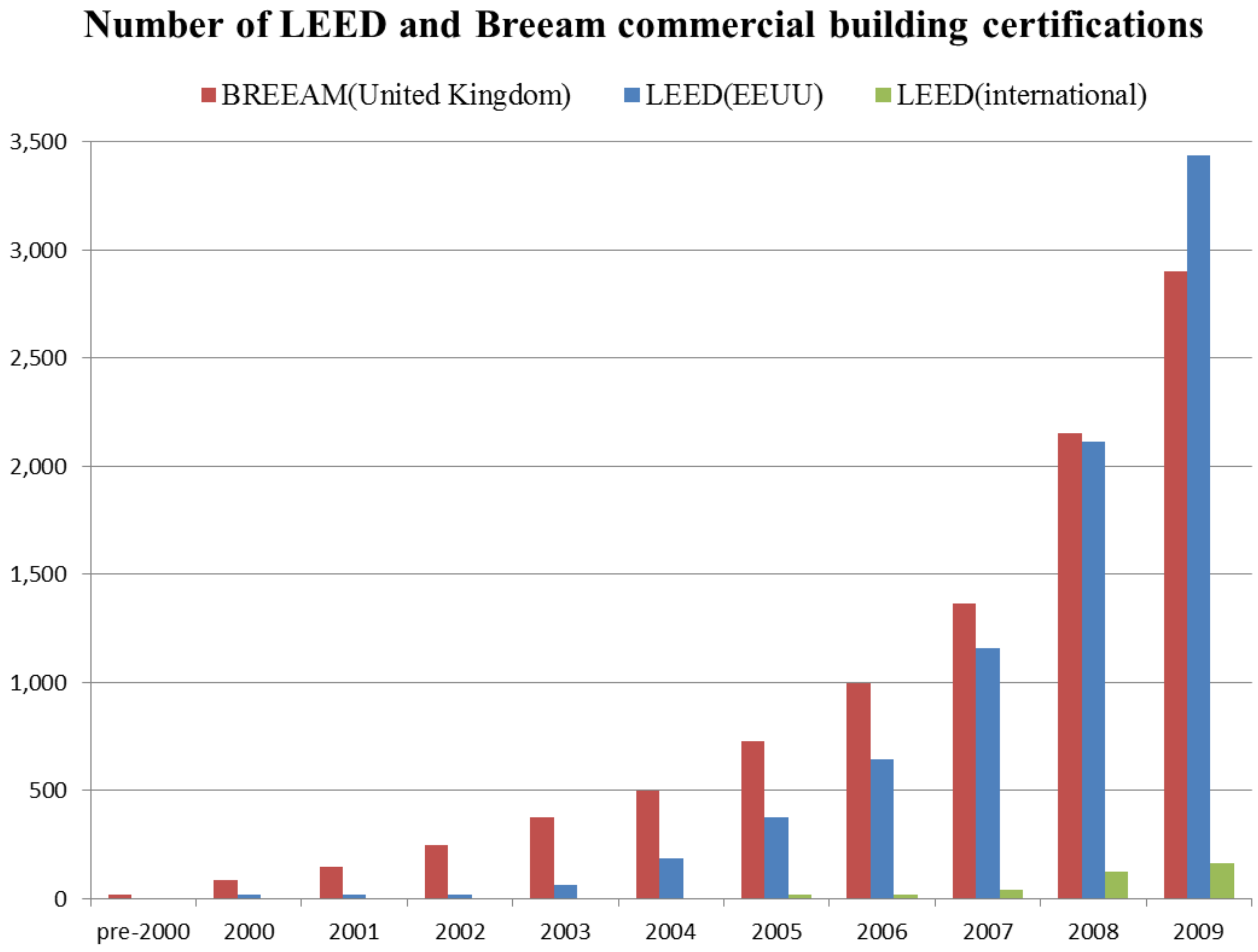
Annen bedriftsspesifikk informasjon

Contiga AS er leverandør av stål- og betongelementer.

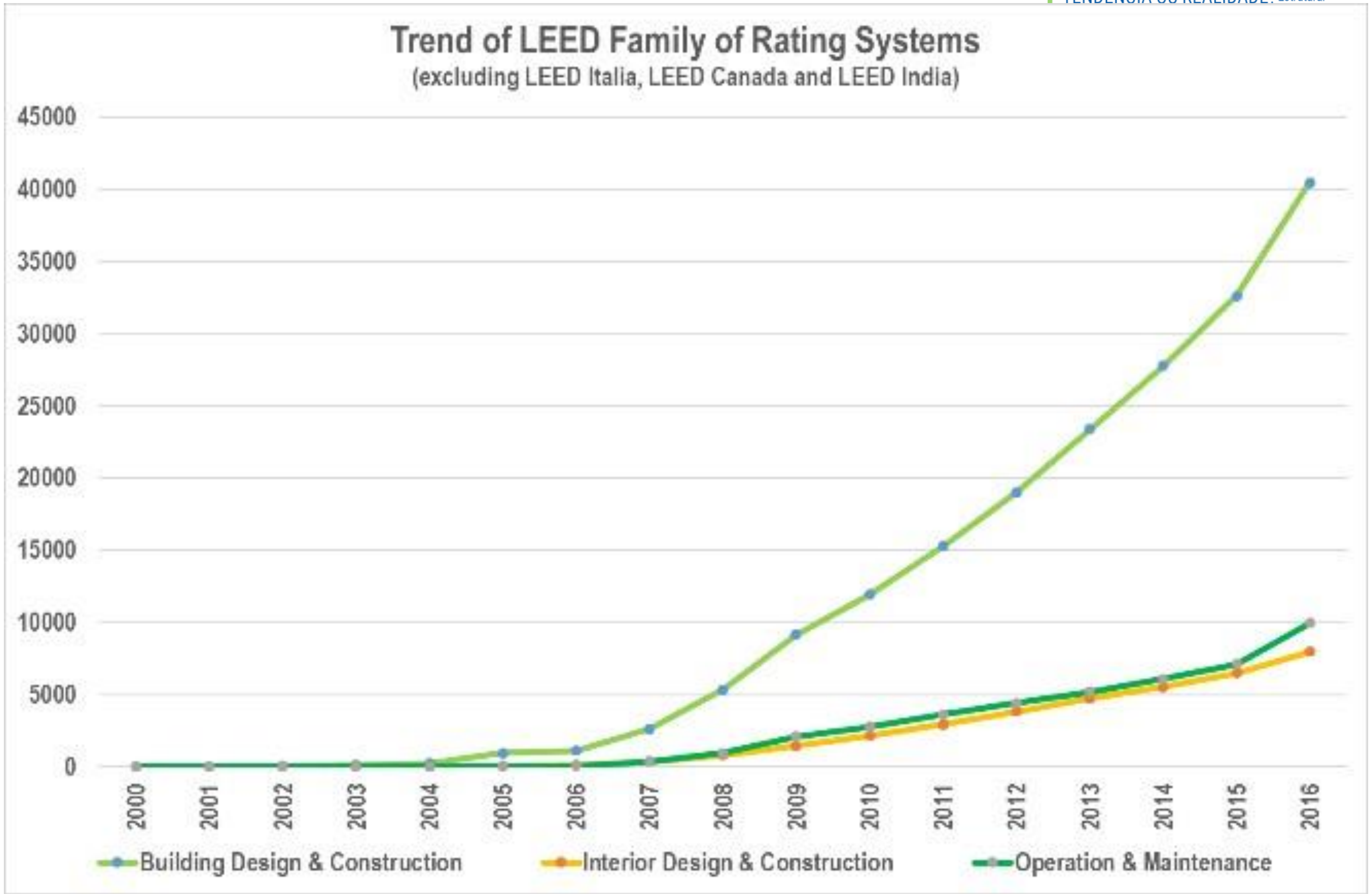
Sustainability certification tools for buildings :

- BREEAM (UK)
- CASBEE (Japan)
- GBTool (International)
- Green Globes TM (Canada)
- LEED (USA)
- Verde (Spain)

Sustainability certification tools for buildings :

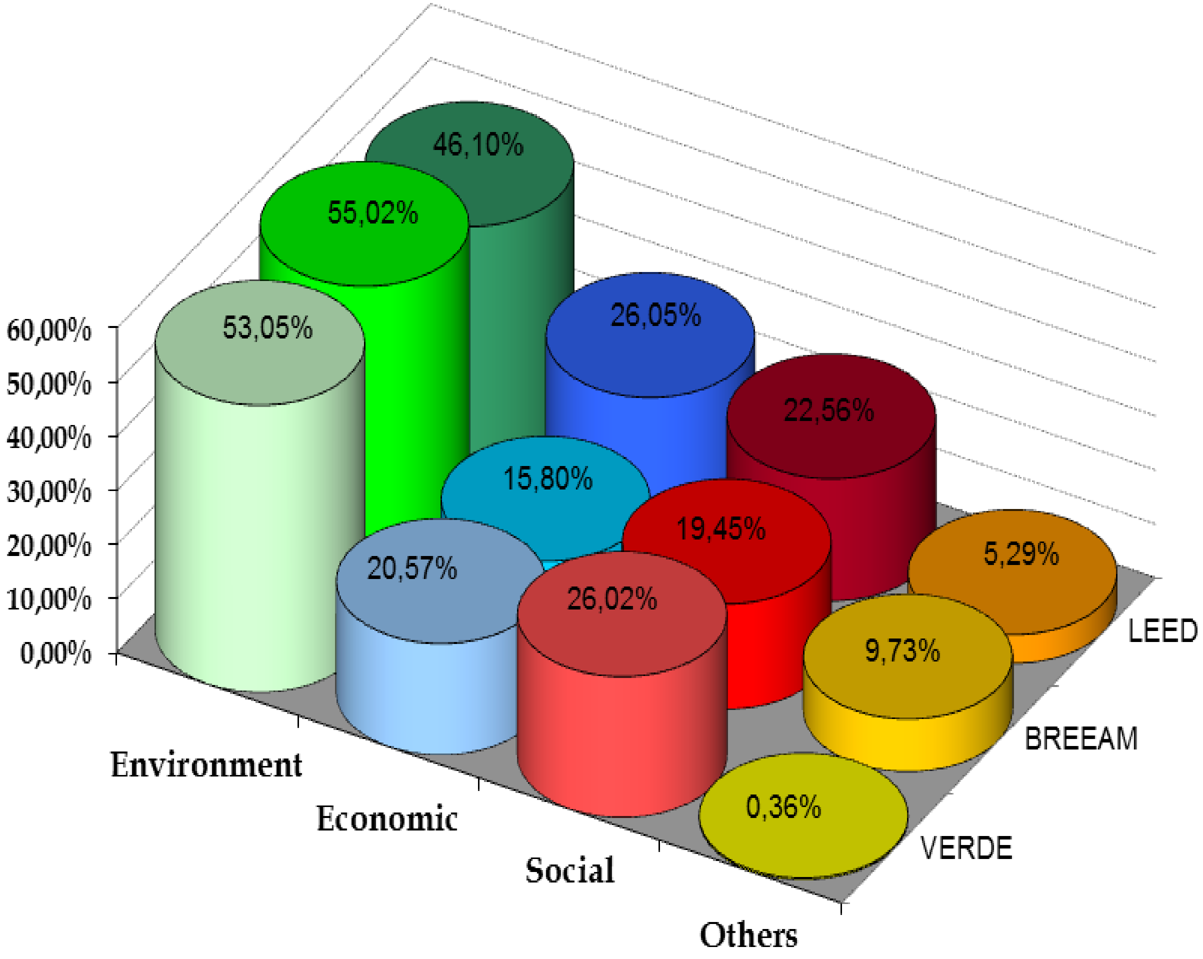


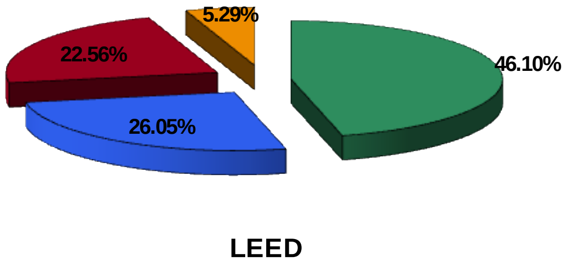
Sustainability certification tools for buildings :

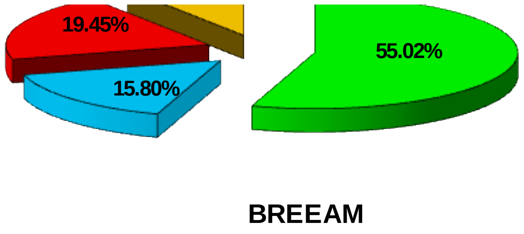


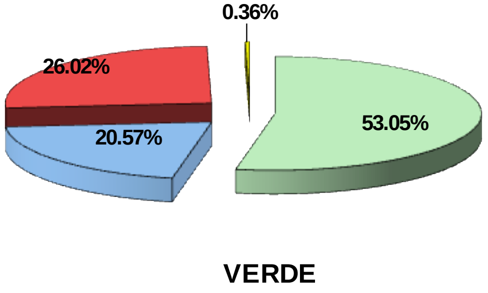
Sustainability certification tools for buildings :

Comparison of parameters between several sustainability tools









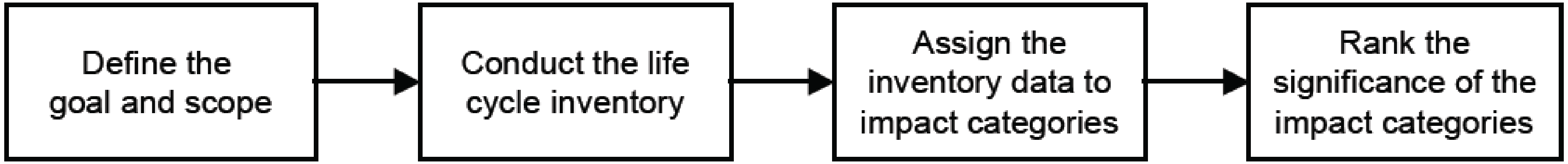
Life-Cycle Assessment:

A life-cycle assessment (LCA) is an environmental assessment of the life cycle of a product.

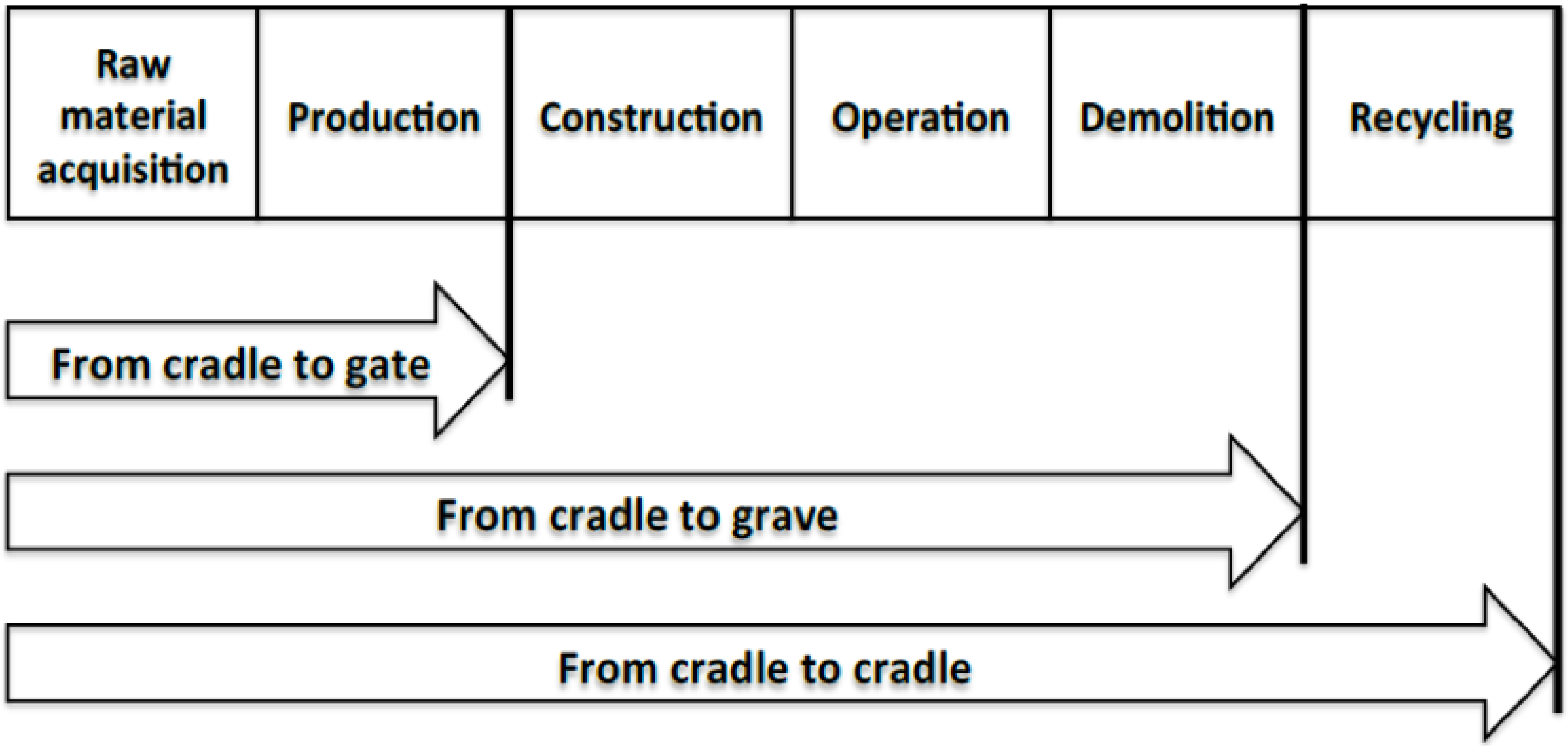
fib Bulletin 71 "Integrated life cycle assessment of concrete structures"

An LCA looks at all aspects of a product life cycle — from the first stages of harvesting and extracting raw materials from nature, to transforming and processing these raw materials into a product, to using the product, and ultimately recycling it or disposing of it back into nature.

A life-cycle assessment consists of these four phases.



Life-Cycle Assessment:



Precast concrete structures

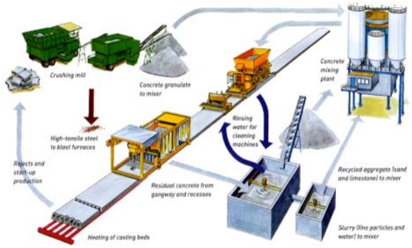
The production of precast concrete elements normally takes place under controlled climatic conditions in enclosed factories. This makes control of waste, emissions, noise levels, etc. easy compared to the same process at a traditional building site. Working environment is also easily controlled.

Moreover the use of new technologies like self-compacting concrete (SCC) can significantly reduce the noise and vibration in the production process. The use of high-performance concrete (HPC) enables design and production of more reliable and more durable structures with optimized shape.

The potential for savings in structural material consumption and consequently natural resources is evident.

Opportunities for prefabrication

Environmentally friendly production



Recycling

New design approach : adaptability
- large spans for interior flexibility
- maximum work in the factory – also for technical equipment

Precast concrete is showing the way

Minimum cement
Thermal mass
Demountability and possible reuse

High strength concrete

Slender components

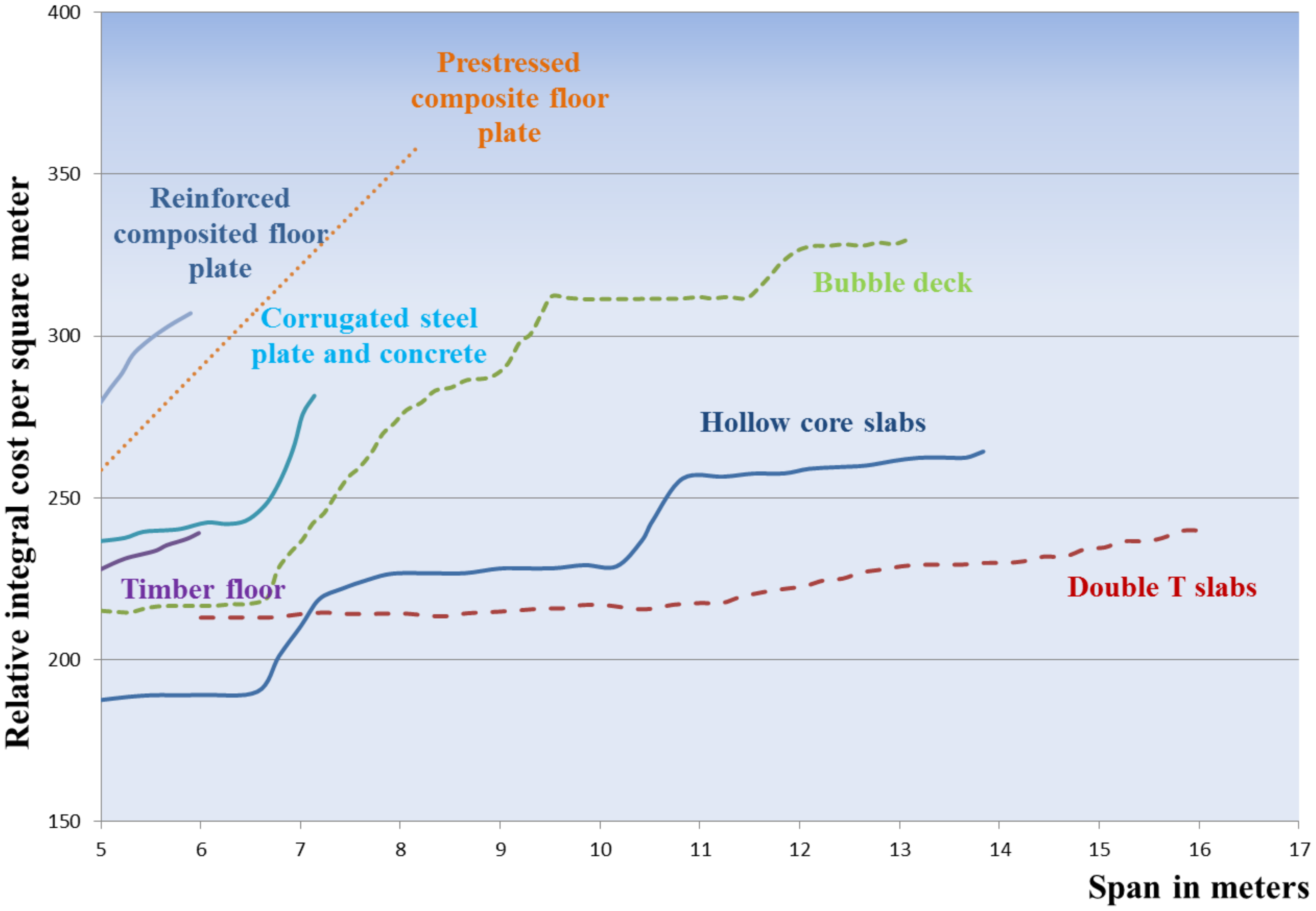
Energy consumption:

In some examples there have been compared the structures of buildings with several heights for buildings of both homes and office. The functional unit is one square meter of ground used by the building for the life of the building, including both horizontal and vertical structural components and supplementary materials, i.e., the total environmental load of the building. Lifetime expectation was taken as 50 years.

Energy consumption to produce floors .

Item	**Hollow core slab (MJ/m^2)**	**Cast in situ slab (MJ/m^2)**
Cement	186	389
Steel	45	60
Other raw materials	15	23
Manufacturing process	128	32
Transportation	28	42
Total	**401**	**560**

Cost of floors:



Relative Costs of different kind of decks for housing. (ClMbéton. Paris 2002)

Environmental impact of floors:

A study in the Netherlands carried out an extensive investigation comparing a precast hollow core floor with a shuttering slab and a cast in situ floor. The results are shown in table:

	Hollow core 1	**Shuttering slab**	**Cast in situ**
Concrete (kg)	263,72	423,00	423,00
Reinforcement (kg)	3,22	6,44	6,11
Total mass (kg)	266,94	429,44	429,11
Eutrophication (kg PO43 eq.)	0,0356	0,0448	0,0410
Exhaustion (x 012)	0,0468	0,0621	0,0707
Ecotoxicity(x103m3)	2,78	5,52	5,81
Greenhouse effect (kg CO_2 eq.)	55,2	58,6	53,4
Acidification (kg SO2 eq.)	0,252	0,321	0,306
Summer smog (kg C2H4 eq.)	0,0297	0,0453	0,0460
Human toxicity (kg)	0,318	0,429	0,411
Use of primary energy (mi)	461	592	643
Solid waste (kg)	36,3	59,6	58,8

The quantities are per square meter. "eq." = equivalents

Comparison of different floor types.

Transport impact in the construction of floors:

A precaster in Norway carried out a comparison: The background was that a new large hospital was being planned, a regional hospital.

	Cast in situ floor			**Precast floor**			**Savings**
	300 and 350 mm fiat slab U-elements	100 mm topping	Sum	200 mm hollow core slabs and 50 mm topping	50 mm Rockwool sound insulation with	Sum	
Area (m^2)	25'000		25'000	25'000		25'000	
Concrete (m^3)	8'000	2'500	10'500	2'880	1'250	4'130	6'370
Concrete(tons)	20'000	6'250	26'250	7'200	3'125	10'325	15'925
No. of truckloads	1'333	417	**1'750**	257	248	**505**	1'245

Possible less transportation in floor construction.

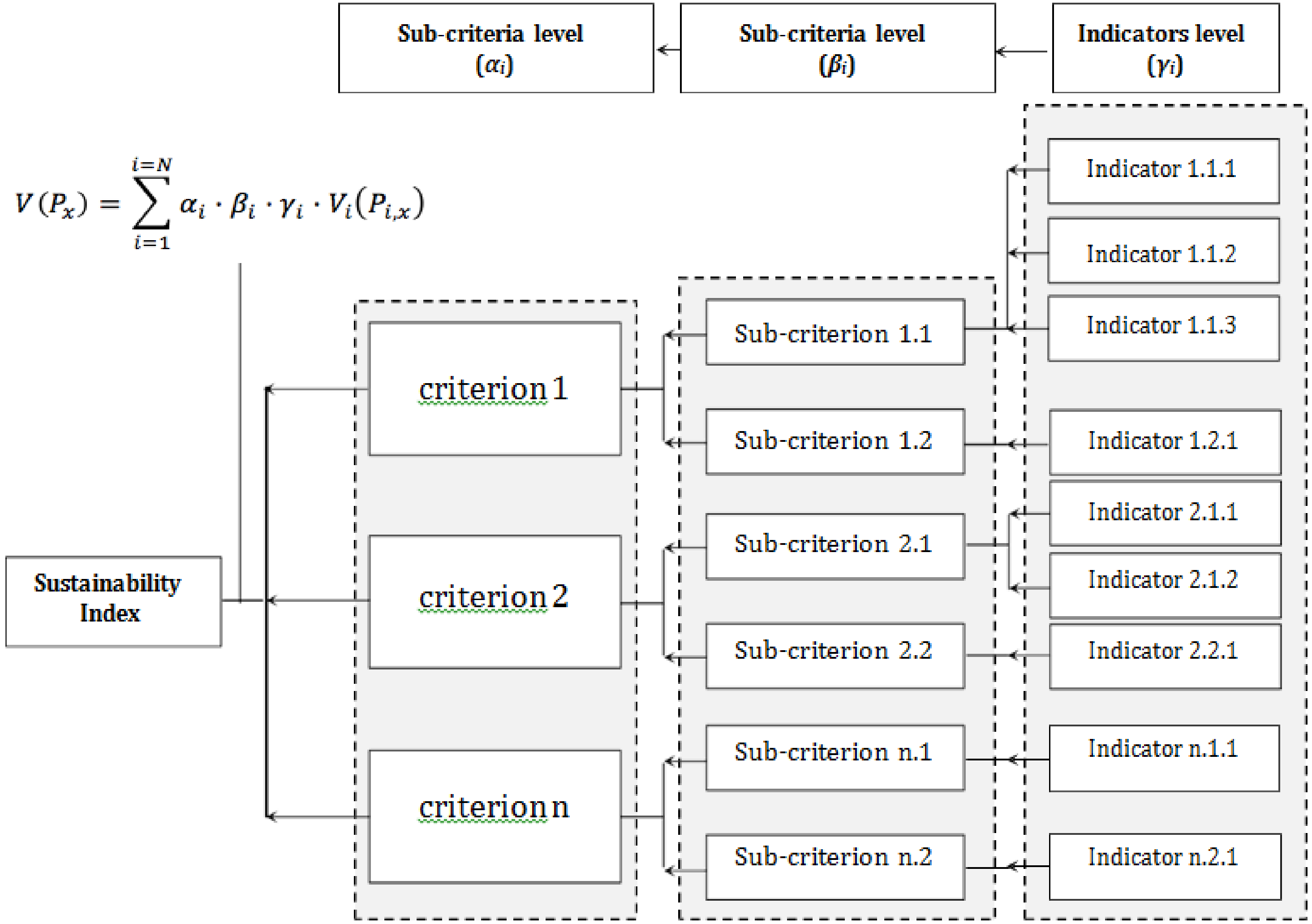
Multi-Criteria Method. General definition:

MIVES is a multi-criteria decision-making method capable of defining specialized and holistic sustainability assessment models to obtain global sustainability indexes.

The method combines:

a) a specific holistic discriminatory tree of requirements;
b) the assignation of weights for each requirement, criteria and indicator;
c) the value function concept to obtain particular and global indexes and
d) seminars with experts using Analytic Hierarchy Process (AHP) to define the aforementioned parts.

Multi-Criteria Method. Requirement tree:



Multi-Criteria Method. Value functions for indicators;

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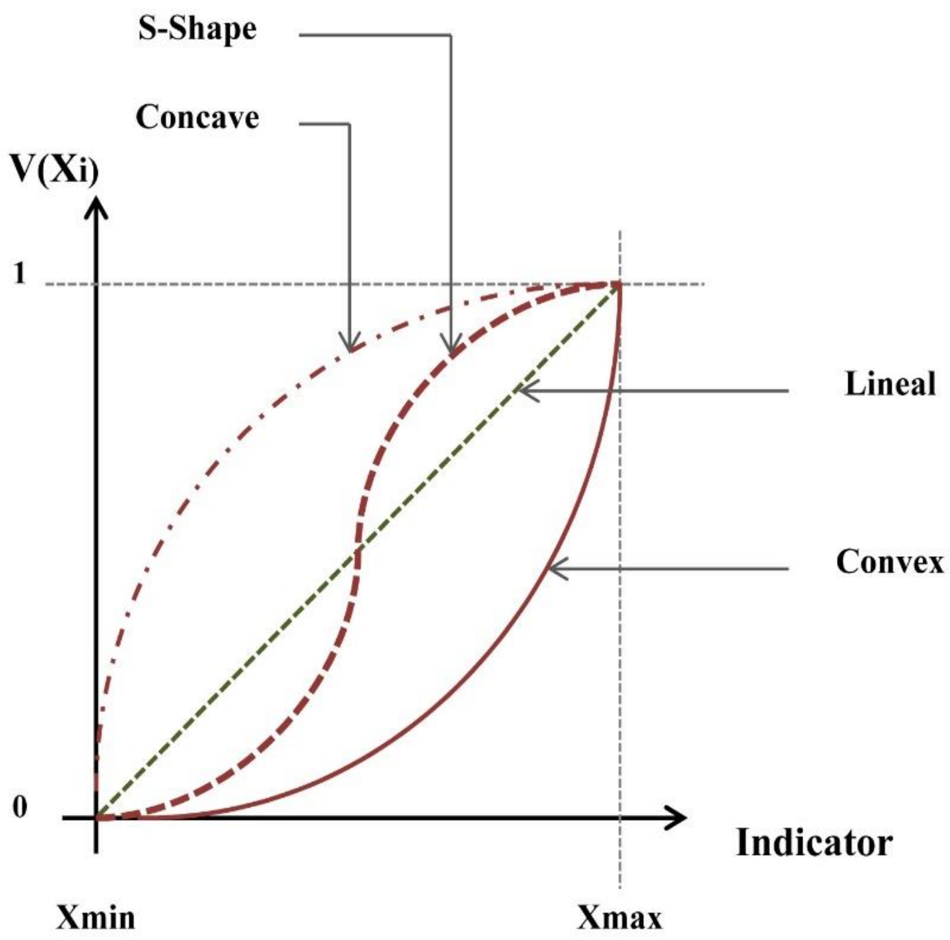
The value function can be increasing or decreasing depending on the nature of the indicator (or measurement variable) to be evaluated.
An increasing function is used when an increase in the measurement variable results in an increase in the decision maker’s satisfaction.
A decreasing value function shows that an increase in the measurement unit causes a decrease in satisfaction.



fib TG6.3. Proposed Tree, Criteria and Indicators:

The members of the *fib* TG 6.3. “Sustainability of precast concrete structures” have assumed MIVES as a suitable tool to deal with the assessment of the sustainability index of precast concrete structures since this fits with the generality and flexibility required for this kind of analyses.

Various seminars were carried out in order to define the approach that the committee propose as a sustainability assessment method for precast concrete structures. As a result, the requirements’ tree presented has been established by the experts.

fib TG6.3. Proposed Tree, Criteria and Indicators:

The requirements' tree presented gathers a total of 9 criteria (C) and 23 indicators (I) which were established as the most representative. From these elements, it can be noticed that:

- The LCA embraces from cradle (from materials' extraction) to the end of life (dismantling, this included). In this sense, other time boundaries could be considered whenever these are more representative of the sustainability assessment to be carried out.
- Increasing and decreasing value functions have been established.
- The units are fixed as to allow measuring either a particular element (eg., panels, beams, columns) or the whole precast concrete structure.
- Attributes were established as a measurement systems for some cases; particularly for those depending on local standards (Health & Safety indicators, for instance) and those with a high statistical component (non-quality costs, which depend on the type of elements, materials used, structural configuration, transport and handling methods, among others).

fib TG6.3. Proposed Tree, Criteria and Indicators:

Requirement	Criteria	Indicator	Units	Value Function
R_1 Economic (λ_{R1} = 35%)	C_1 Total Costs (λ_{C1} = 42%)	I_1 Direct and indirect costs (λ_{I1} = 100%)	€	DS
	C_2 Quality (λ_{C2} = 19%)	I_2 Non quality costs (λ_{I2} = 100%)	Attrib.	
	C_3 Dismantling (λ_{C3} = 9%)	I_3 Dismantling costs (λ_{I3} = 100%)	€	DS
	C_4 Service Life (λ_{C4} = 30%)	I_4 Service costs (λ_{I4} = 61%)		
		I_5 Resilience (λ_{I5} = 39%)		IS
R_2 Environmental (λ_{R2} = 38%)	C_5 Consumption (λ_{C5} = 44%)	I_6 Cement (λ_{I6} = 22%)	Ton	DS
		I_7 Aggregates (λ_{I7} = 21%)		
		I_8 Steel (λ_{I8} = 21%)		
		I_9 Water (λ_{I9} = 12%)		
		I_{10} Plastics and others (λ_{I10} = 10%)		
		I_{11} Reused materials (λ_{I11}= 14%)		IS
	C_6 Emissions (λ_{C6} = 32%)	I_{12} CO_2 emissions (λ_{I12} = 62%)	$TnCO_2$-eq	DS
		I_{13} Total waste (λ_{I13} = 38%)	Ton	
	C_7 Energy (λ_{C7} = 24%)	I_{14} Materials (λ_{I14}= 37%)	MWh	
		I_{15} Construction (λ_{I15}= 26%)		
		I_{16} Service (λ_{I16}= 37%)		
R_3 Social (λ_{R3} = 26%)	C_8 Third parties (λ_{C8} = 37%)	I_{17} Comfort (λ_{I17} = 52%)	Attrib.	
		I_{18} Noise pollution (λ_{I18} =15%)	Db.	
		I_{19} Particles pollution (λ_{I19} = 20%)	Ton	
		I_{20} Traffic disturbances (λ_{I20} = 13%)	Attrib.	
	C_9 Health and Safety (λ_{C9} = 63%)	I_{21} Risks. Production (λ_{I21} = 23%)		
		I_{22} Risks. Construction (λ_{I22} = 23%)		
		I_{23} Risks. Service life (λ_{I23} = 55%)		

fib TG6.3. Proposed Tree, Variability:

A survey was distributed among the *fib* TG 6.3 members in order to establish the potential weights to be used in the requirements' tree. A total of twelve (12) weighs' distributions were obtained and, from these, different statistical studies were carried out. In this regard, it must be highlighted that the weights gathered respond to the average values obtained from the survey.

	λ_{Rim}	$CV_{\lambda R}$	$\lambda_{Ri,min}$	$\lambda_{Ri,max}$
Economic (R_1)	35%	23%	30%	40%
Environmental (R_2)	38%	16%	33%	50%
Social (R_3)	26%	33%	10%	33%
Others (R_4)	0%	33%	10%	33%

fib TG6.3. Proposed Tree, Comparison with other tools:

In terms of comparison with other sustainability or certification tools for buildings, this table gathers the weights' distribution proposed in these alternative sustainability assessment approaches.

	fib TG 6.3	LEED	BREAM	VERDE	DGNB	LEnSE	SBToolCZ	λ_{Rim}	$CV_{\lambda R}$	$\lambda_{Ri,min}$	$\lambda_{Ri,max}$
Economic (R_1)	35%	26%	16%	21%	33%	19%	15%	24%	34%	15%	35%
Environmental (R_2)	38%	46%	55%	53%	33%	44%	50%	46%	17%	33%	55%
Social (R_3)	26%	23%	20%	26%	33%	37%	35%	29%	22%	20%	37%
Others (R_4)	0%	5%	10%	0%	0%	0%	0%	2%	-	0%	10%

Table 4. Weights' distributions for various sustainability/certification tools for buildings

The data gathered reflect that the average value of the economic requirement weight is reduced to 24% respect to the 35% agreed in the *fib* TG 6.3 whilst the environmental requirement weight increases up to 46% in contrast the 38% assumed in the *fib* committee. Finally, average values between 25%-30% for the social requirement weight seems to be well-accepted.

It is important to note that the environmental sensitivity is high independently of the assessment method since values ranging from 33% to 55%, with variation coefficient 17%, have been found.

Application example. Concrete columns for buildings:

The most representative criteria and indicators to deal with the sustainability assessment of building columns according to the experts involved in the seminar carried out for this study case are:

Requirements	Criteria	Indicators and value function shape
R_1. Economic (50%)	C_1. Construction costs (67%)	I_1. Building costs (85%, DS)
		I_2. Non acceptance costs (15%, IL)
	C_2. Efficiency (33%)	I_3. Maintenance (60%, DS)
		I_4. Habitability (40%, DCv)
R_2. Environmental (33%)	C_3. Emissions (67%)	I_5. CO_2 emissions (100%, DS)
	C_4. Resources consumption (33%)	I_6. Concrete consumption (90%, DCv)
		I_7. Steel consumption (10%, DCx)
R_3. Social (17%)	C_5. Negative effects (80%)	I_8. Workers' inconveniences (20%, DS)
		I_9. Workers' safety (80%, IL)
	C_6. Third parties (20%)	I_{10}. Environment nuisances (100%, IL)

Application example. Concrete columns for buildings:

The results from the case study carried out are:

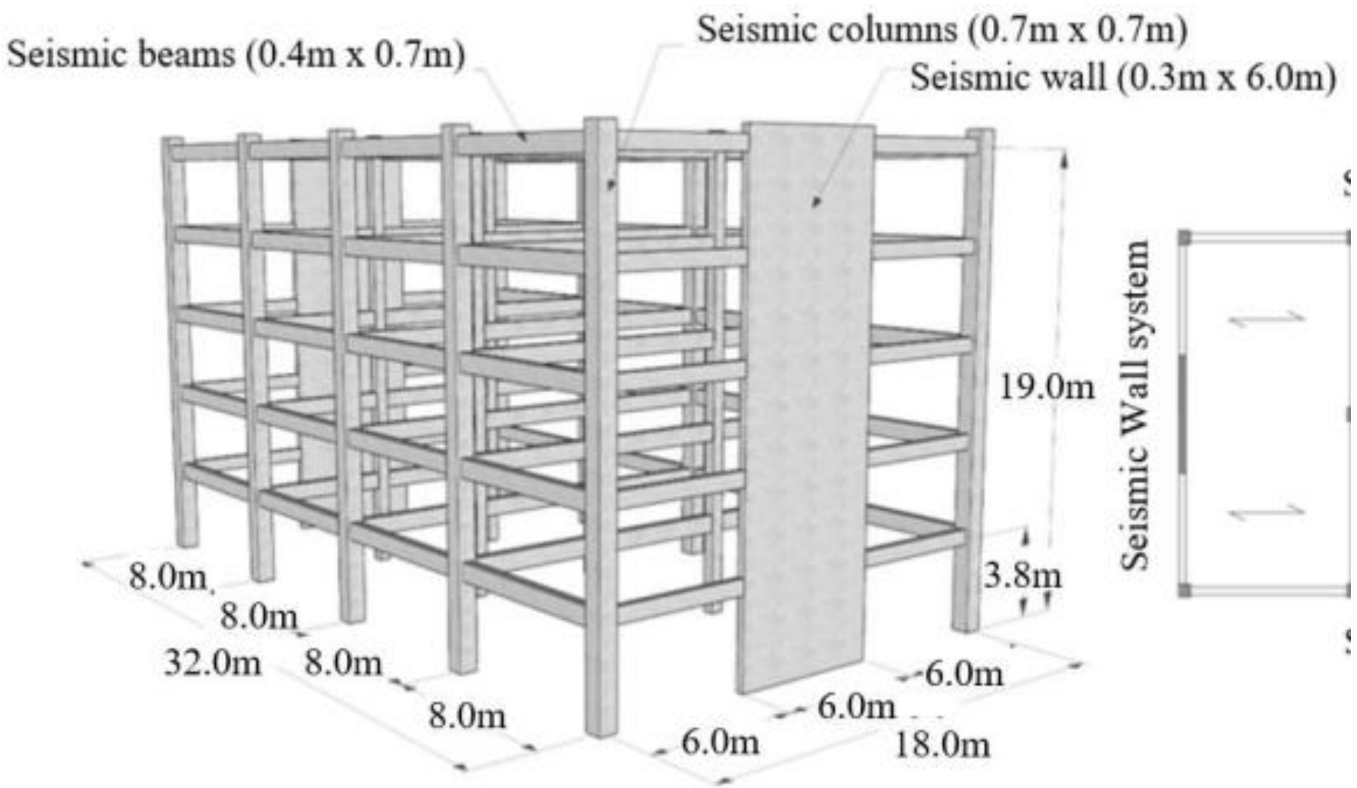
Alternative	Compressive strength (N/mm^2)	Cross-section (cm)	Vibration Process	Sustainability Index (SI)
Circular 1	25	Ø 50	Self-compacting	0.56
Circular 2			Vibrated	0.56
Circular 3	50	Ø 35	Self-compacting	0.77
Circular 4			Vibrated	0.72
Circular 5	75	Ø 30	Self-compacting	0.85
Circular 6			Vibrated	0.89
Square 1	25	40 x 40	Self-compacting	0.62
Square 2			Vibrated	0.61
Square 3	50	30 x 30	Self-compacting	0.72
Square 4			Vibrated	0.66
Square 5	75	25 x 25	Self-compacting	0.77
Square 6			Vibrated	0.71

Application example. Concrete columns for buildings:

As a result of this sustainability assessment, it can be concluded that:

- The most sustainable columns are those with smaller cross-sections and are built using high compressive strength concretes.
- Columns made of self-compacting concrete have a higher SI than those vibrated.
- Circular columns are more sustainable than those square or rectangular shaped due to aesthetic and functional reasons.
- Circular columns have a higher index when using high performance concrete and having small cross-section areas while square and rectangular alternatives are more sustainable when using conventional concretes and having bigger cross-sections

Case study



Cast on site

Precast

fib TG6.3. Second document: Application to a precast concrete building

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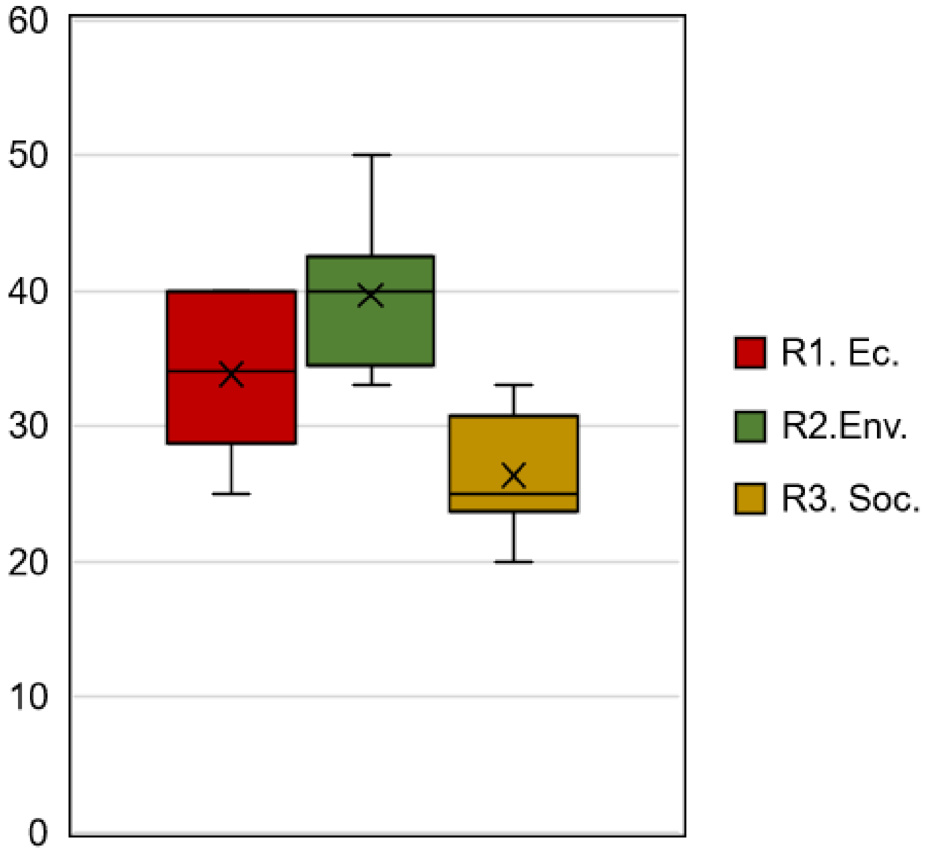
Model developed: decision-making tree

Requirement		Criteria		Indicators	
R1. Economic	36%	C1. Cost	61%	I1. Direct	61%
				I2. Indirect	6%
				I3. Rehabilitation	11%
				I4. Dismantling	21%
		C2. Time	39%	I5. Production & Assembly	100%
R2. Environmental	39%	C3. Emissions	55%	I6. Emissions of CO2-eq	100%
		C4. Energy	19%	I7. Energy consumption	100%
		C5. Materials	26%	I8. Index of Efficiency	100%
R3. Social	25%	C6. Safety	60%	I9. Index of Risk	100%
		C7. Third parties' affectations	40%	I10. Social Benefits	55%
				I11. Disturbances in construction	45%

Model developed: weights

Requirement	
R1. Economic	36%
R2. Environmental	39%
R3. Social	25%

Participatory approach

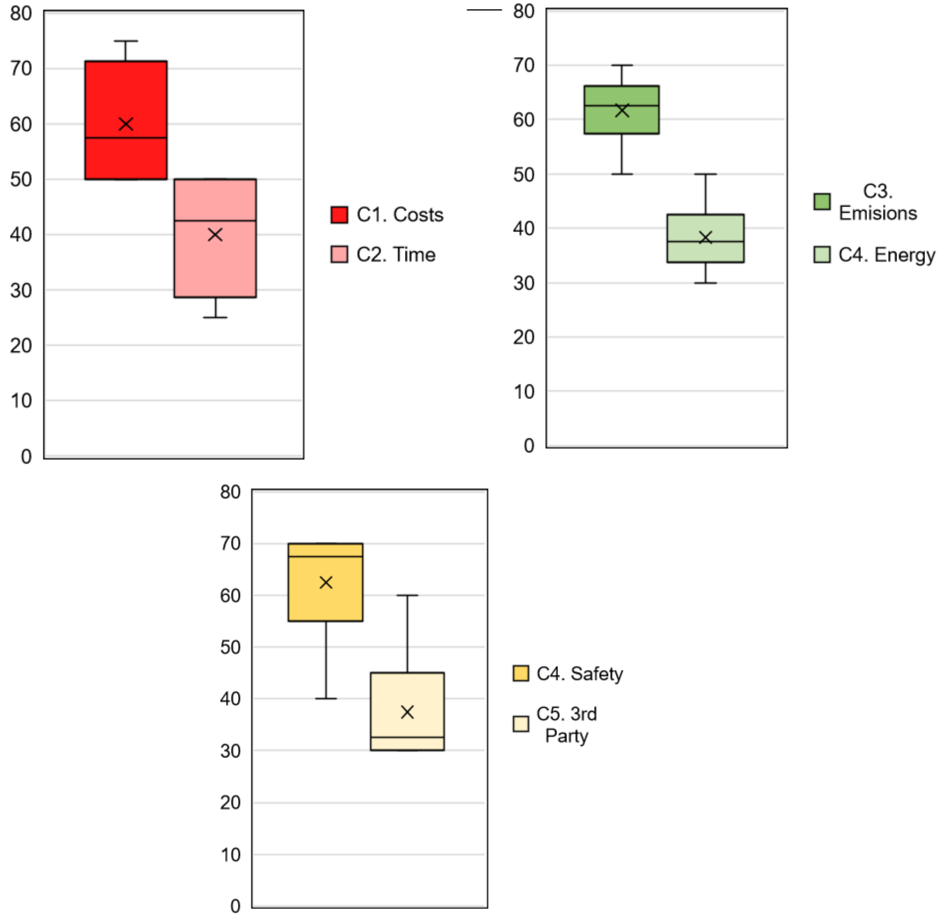


fib TG6.3. Second document: Application to a precast concrete building

Model developed: weights

Participatory approach

Requirement		Criteria	
R1. Economic	36%	C1. Cost	61%
		C2. Time	39%
R2. Environmental	39%	C3. Emissions	55%
		C4. Energy	19%
		C5. Materials	26%
R3. Social	25%	C6. Safety	60%
		C7. Third parties' affectations	40%

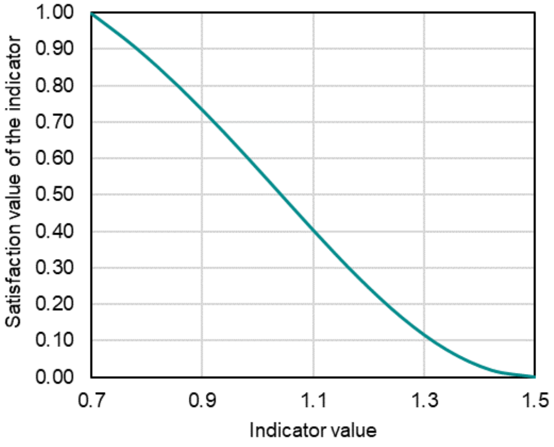


fib TG6.3. Second document: Application to a precast concrete building

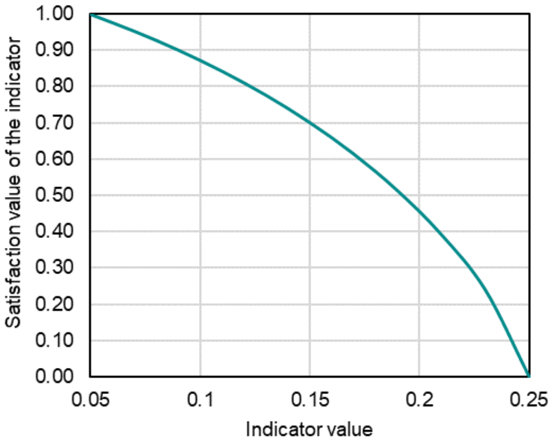
Model developed: indicators

ECONOMIC

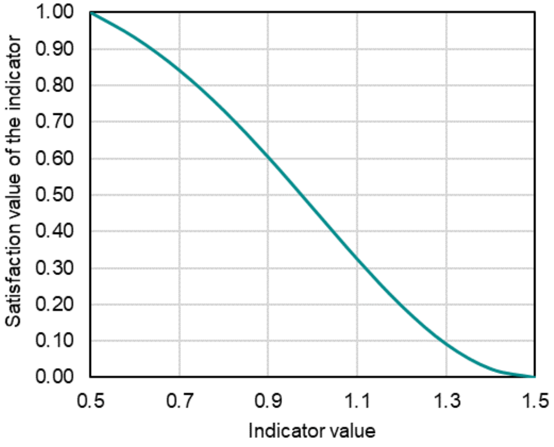
Direct costs



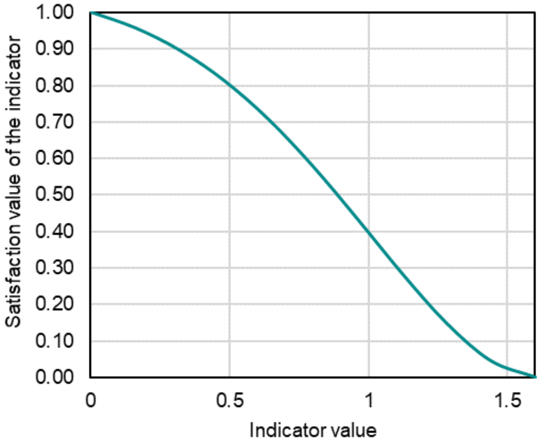
Indirect costs



Rehabilitation costs
Dismantling costs



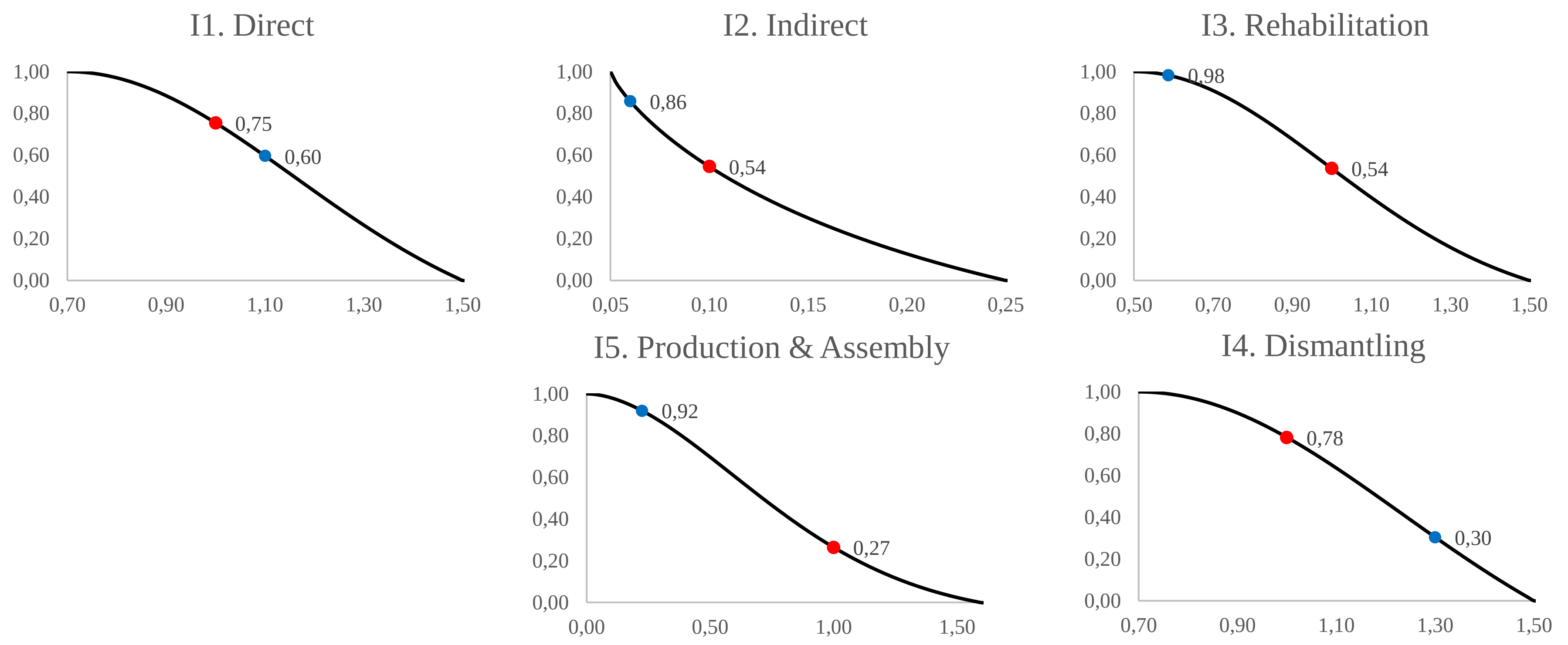
Production and assembly time



fib TG6.3. Second document:
Application to a precast concrete building

Model developed: indicators

ECONOMIC



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Application to a precast concrete building

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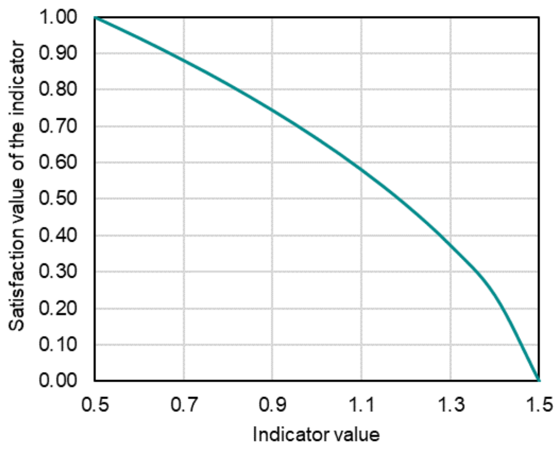
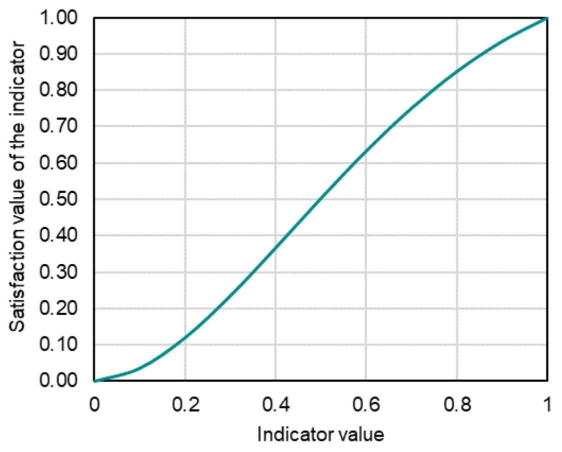
ENVIRONMENTAL

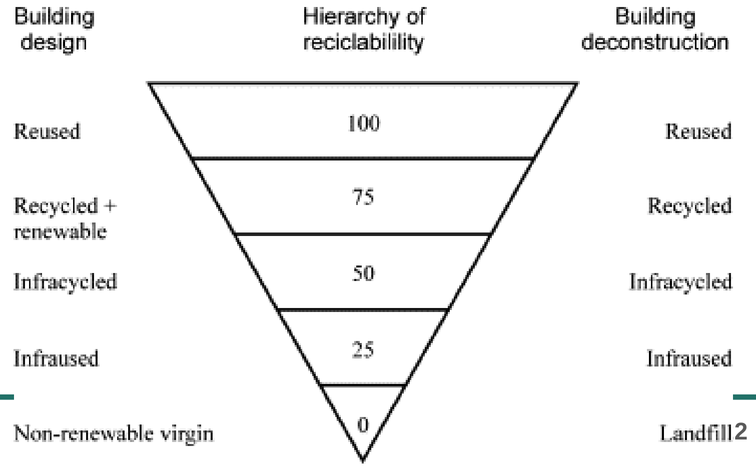
Equivalent CO_2 emissions
Energy consumption



Derived from LCA

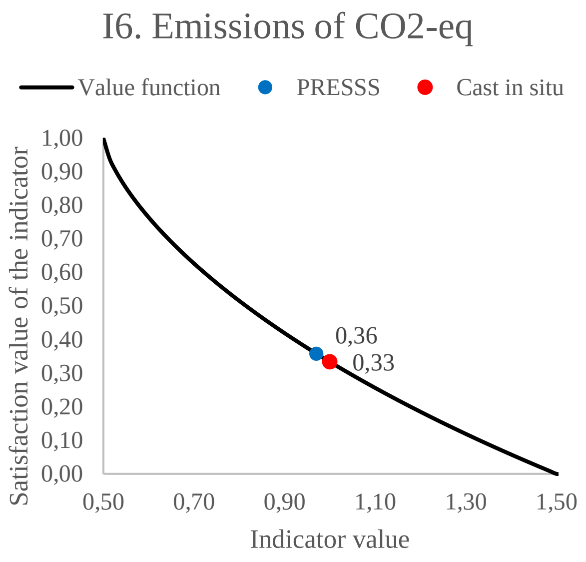
Material efficiency index

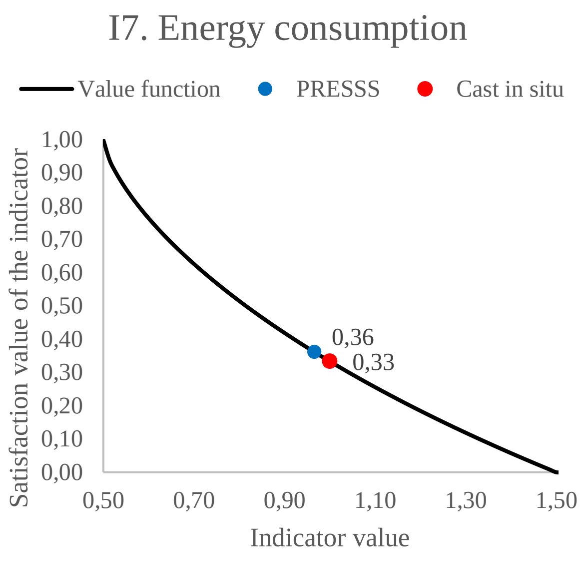


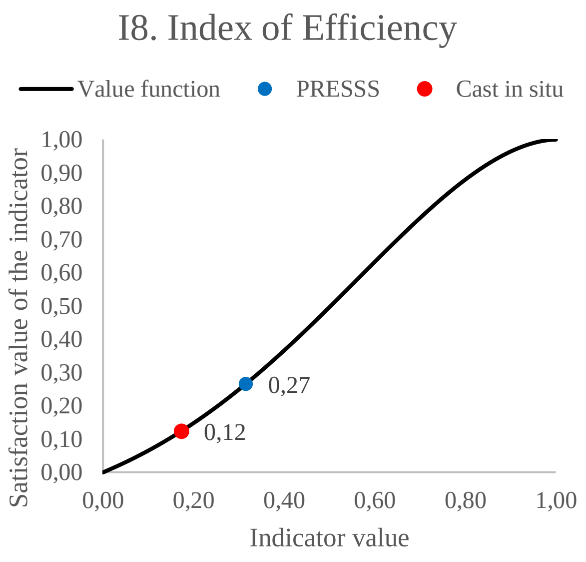


Model developed: indicators

ENVIRONMENTAL





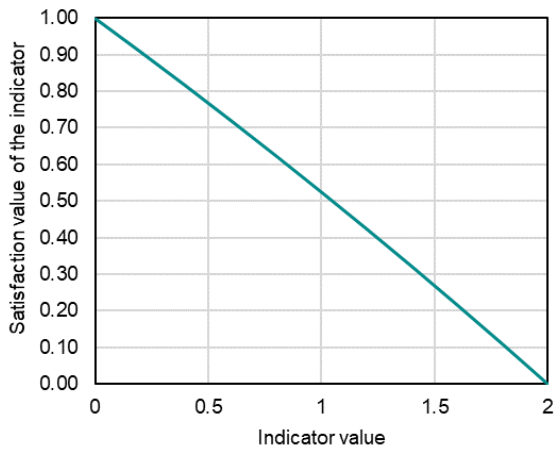


fib TG6.3. Second document: Application to a precast concrete building

Model developed: indicators

SOCIAL

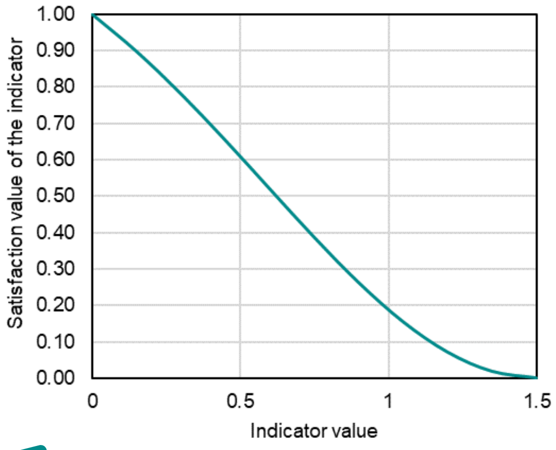
Safety



Calculated using the Occupational Risk Index (ORI)

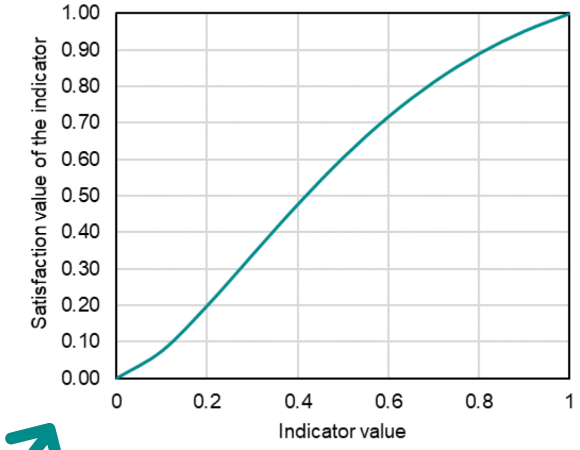
Risk - ACTIVITY - Sub-activity	Weight Exposure	N° workers	Total Exposure
	h	-	
R.1 Fall to lower levels - working at height or depths of more 2m	152	33	463.1
R.8 Collision with or entrapment by moving loads	79	38	481.1
R.9 Blows to upper and lower limbs	16	0	0.0

Social benefits



Calculated considering services downtime

Disturbances in construction

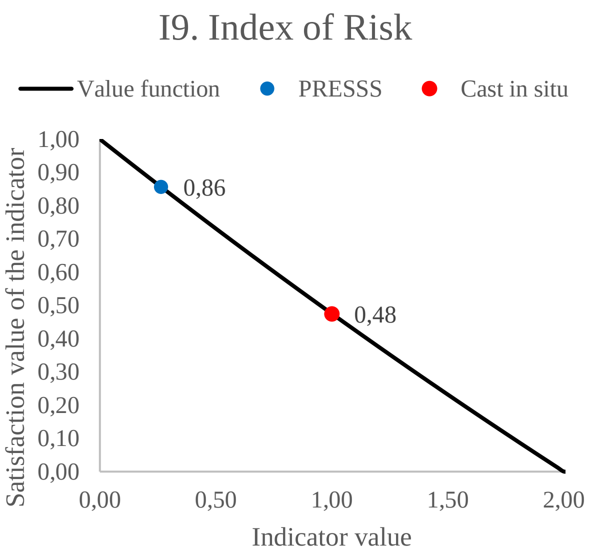


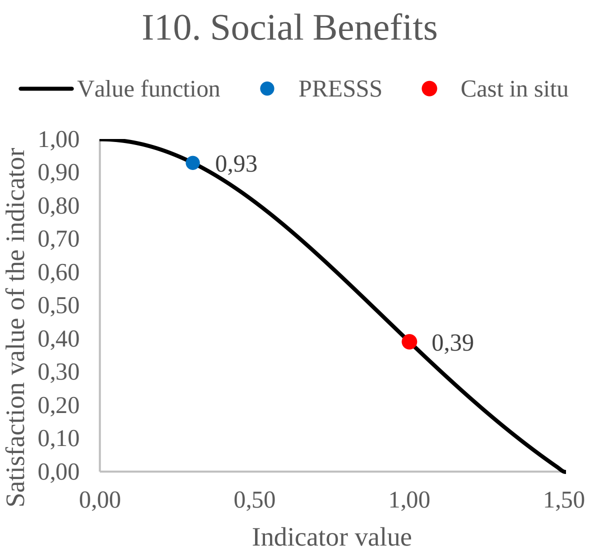
Calculated considering noise pollution and transit/traffic disturbance *fib* TG6.3. Second document:

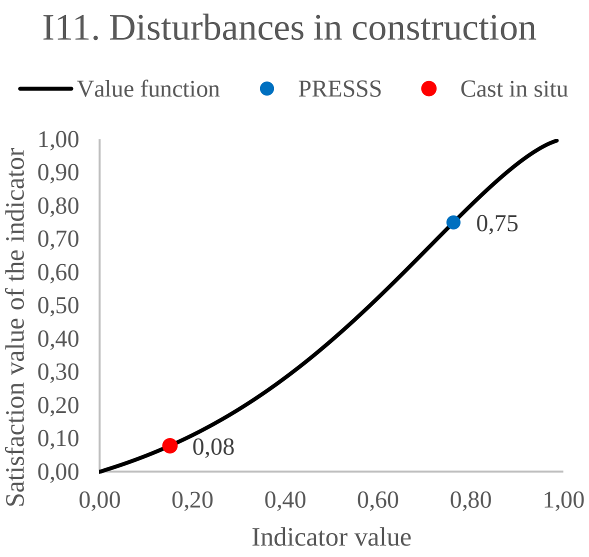
Application to a precast concrete building

Model developed: indicators

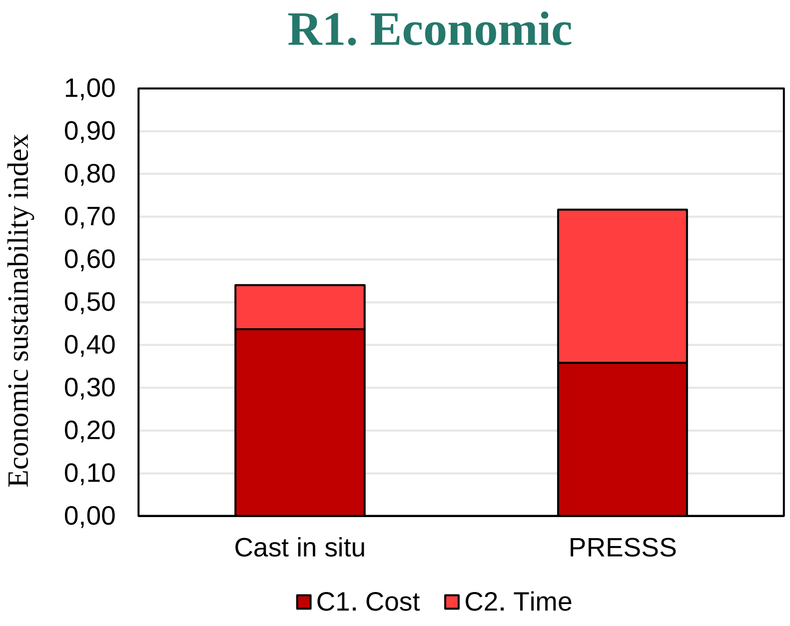
SOCIAL

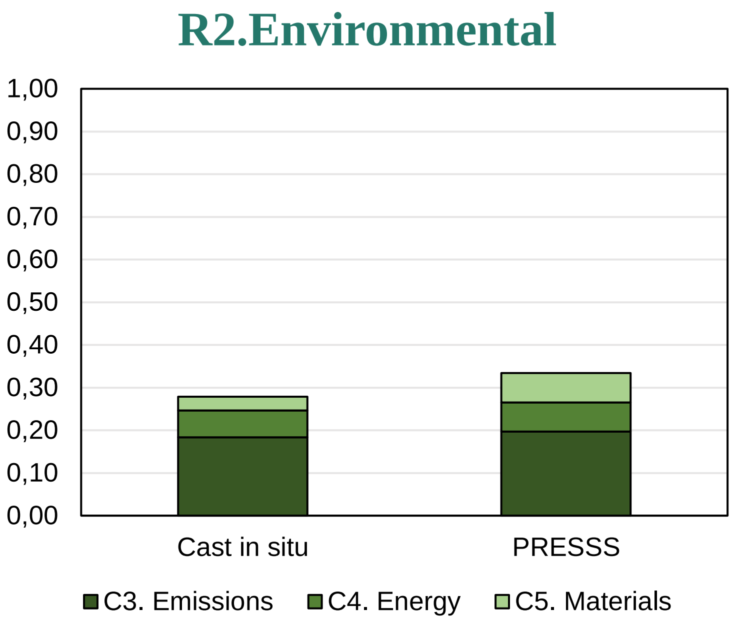


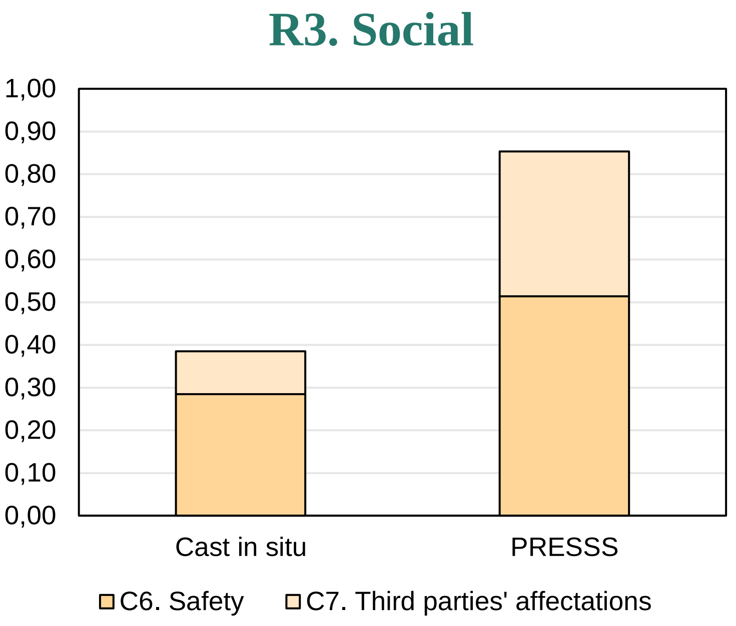




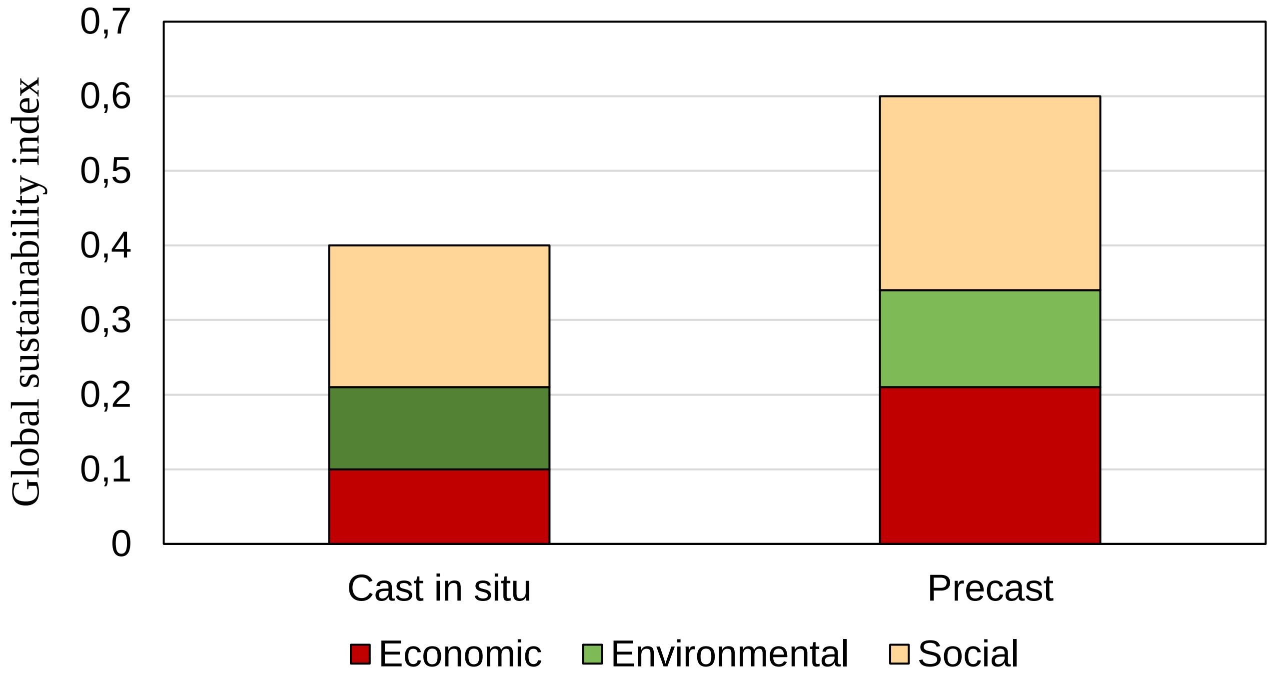
Case study: results







Case study: results



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Conclusions:

- In this case study, the results obtained showed that the **prefabricated solution** was **more sustainable** than the on-site one.
  - From an **economic** point of view, although the traditional solution has lower overall costs, the prefabricated solution is characterized by faster construction and repair times.
  - Regarding **environmental** aspects, results showed the convenience of precast concrete especially from the point of view of the efficiency of materials that can be more easily recycled or reused.
  - From a **social** point of view, the precast solution proved to be far superior to the one cast in place due to the lower exposure to the risks and disturbances caused in the construction phase.

International Federation for Structural Concrete
Fédération internationale du béton

David Fernández-Ordóñez

fib Secretary General