
Gordon Research Conferences
frontiers of science
Advanced Materials for Sustainable Infrastructure Development
The Science and Technology of Sustainable Concrete
The HK University of Science and Technology
July 31 - August 5, 2016
Hong Kong / China

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Advanced Materials for Sustainable Infrastructure Development

The Science and Technology of Sustainable Concrete

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Gordon Research Conferences *frontiers of science*

Durability and High Performance Concrete
The Best Way to Sustainable Concrete Structures

Paulo Helene

Counselor IBRACON
Director PhD Engenharia
Red PREVENIR CYTED Member
Titular Professor of University of São Paulo USP
fib (CEB-FIP) Member of Model Code for Service Life
Honorary President of Asociación Latino Americana de Control de Calidad, Patología y Recuperación de la Construcción ALCONPAT Int.

PhD Engenharia
"do Laboratório de Pesquisa ao Canteiro de Obras"

The HK University of Science and Technology July 31 - August 5, 2016 Hong Kong / China

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Sustainability

"Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs."

United Nations, 1987 - Brundtland Commission

Environmental – Social - Economical

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Leadership for a sustainable culture
(Eng. Darío Ibarguengoitia)

- It is not a luxury design and build with sustainable bases, but it is a commitment from which we cannot run away.
- "Now more than ever sustainability cannot be conceived if not through a holistic, integrated design, which means a very close collaboration between architects and engineers, listen to everyone."

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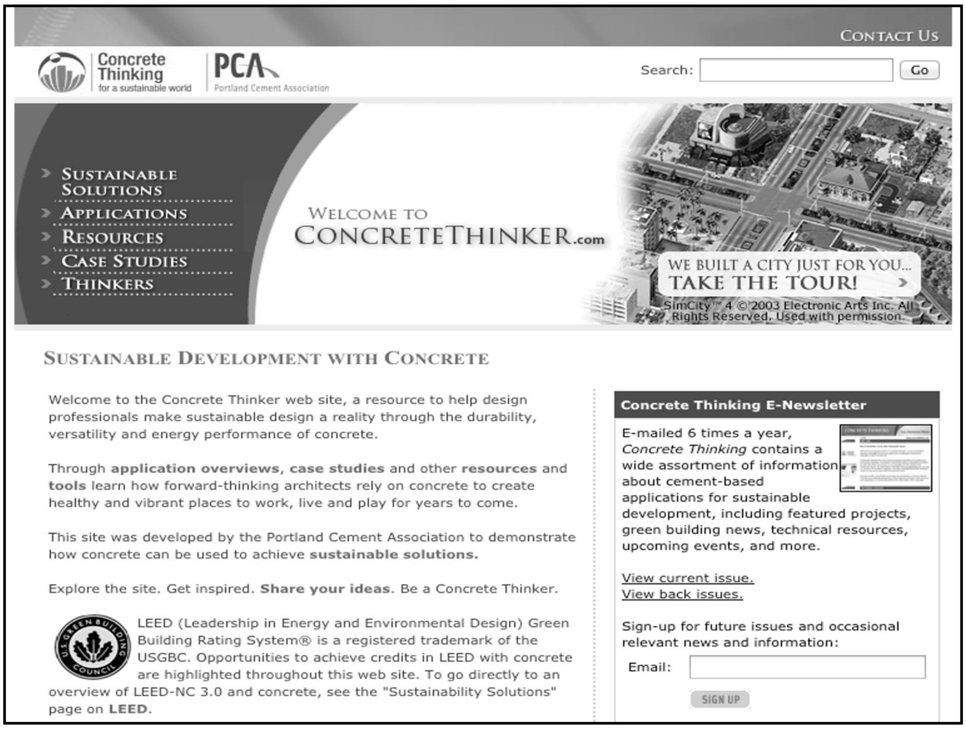

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Concrete Thinking for a sustainable world
PCA Portland Cement Association
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Thinkers
Welcome to ConcreteThinker.com
We built a city just for you... Take the tour!
SimCity™ 4 © 2003 Electronic Arts Inc. All Rights Reserved. Used with permission.
Sustainable Development with Concrete
Welcome to the Concrete Thinker web site, a resource to help design professionals make sustainable design a reality through the durability, versatility and energy performance of concrete.
Through application overviews, case studies and other resources and tools learn how forward-thinking architects rely on concrete to create healthy and vibrant places to work, live and play for years to come.
This site was developed by the Portland Cement Association to demonstrate how concrete can be used to achieve sustainable solutions.
Explore the site. Get inspired. Share your ideas. Be a Concrete Thinker.
LEED (Leadership in Energy and Environmental Design) Green Building Rating System® is a registered trademark of the USGBC. Opportunities to achieve credits in LEED with concrete are highlighted throughout this web site. To go directly to an overview of LEED-NC 3.0 and concrete, see the "Sustainability Solutions" page on LEED.
Concrete Thinking E-Newsletter
E-mailed 6 times a year, Concrete Thinking contains a wide assortment of information about cement-based applications for sustainable development, including featured projects, green building news, technical resources, upcoming events, and more.
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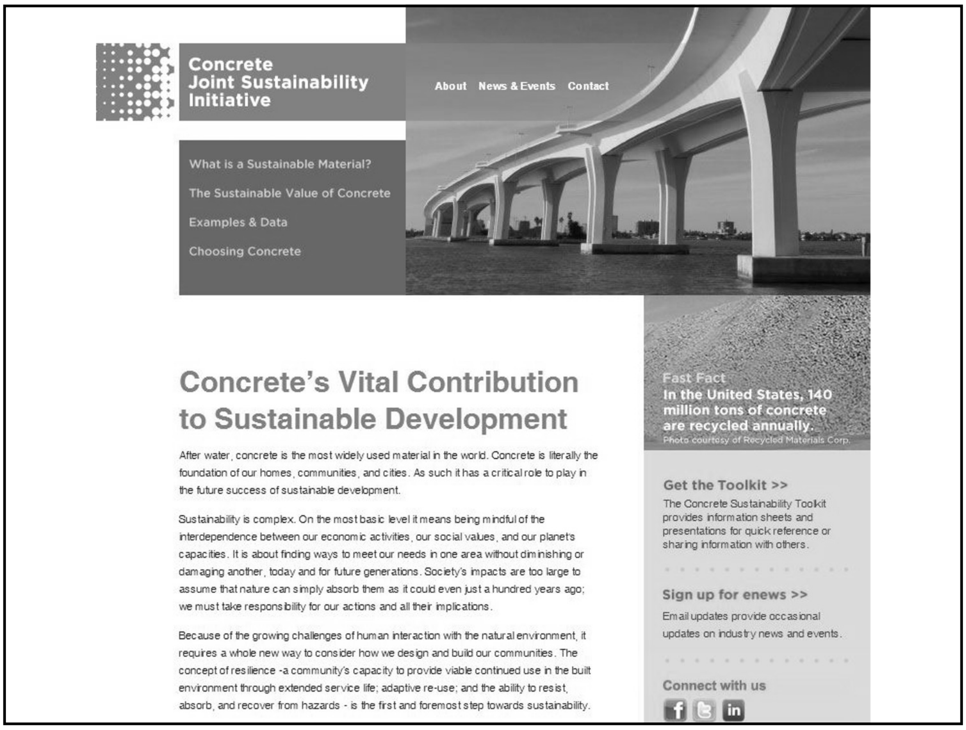

Concrete Joint Sustainability Initiative
About
News & Events
Contact
What is a Sustainable Material?
The Sustainable Value of Concrete
Examples & Data
Choosing Concrete
Concrete's Vital Contribution to Sustainable Development
After water, concrete is the most widely used material in the world. Concrete is literally the foundation of our homes, communities, and cities. As such it has a critical role to play in the future success of sustainable development.
Sustainability is complex. On the most basic level it means being mindful of the interdependence between our economic activities, our social values, and our planets capacities. It is about finding ways to meet our needs in one area without diminishing or damaging another, today and for future generations. Society's impacts are too large to assume that nature can simply absorb them as it could even just a hundred years ago; we must take responsibility for our actions and all their implications.
Because of the growing challenges of human interaction with the natural environment, it requires a whole new way to consider how we design and build our communities. The concept of resilience -a community's capacity to provide viable continued use in the built environment through extended service life; adaptive re-use; and the ability to resist, absorb, and recover from hazards - is the first and foremost step towards sustainability.
Fast Fact
In the United States, 140 million tons of concrete are recycled annually.
Photo courtesy of Recycled Materials Corp.
Get the Toolkit >>
The Concrete Sustainability Toolkit provides information sheets and presentations for quick reference or sharing information with others.
Sign up for enews >>
Email updates provide occasional updates on industry news and events.
Connect with us

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International Documents

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ACI CONCRETE SUSTAINABILITY FORUM VII
Washington DC. October 29, 2014

The preparation of ACI 130R *"Guideline to Concrete Sustainability"* was discussed, sustainability requirements and *fib* Model Code for Concrete Structures, new materials for low-carbon cement and concrete systems, innovations in the cement industry for the purpose of reducing carbon emissions, sustainable paving program

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Environmental Design of Concrete Structures – general principles

TASK GROUP 3.6, Lausanne: ***fib***, 2008. (Bulletin 47).

It is expected that the concrete construction industry contribute to realizing a sustainable society by establishing one design and construction procedures with environmentally correct development of the needed technologies.

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Environmental Design of Concrete Structures – general principles

- This report provides general principles and necessary considerations conferred on the environmental impacts when designing, constructing, dosing, using, maintaining/managing, demolishing, removing and reusing the concrete structure.
- One of the main points is the reduction of raw materials use

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- Other ***fib*** (*fedération internationale du beton*) comissions develop studies regarding sustainability.

- In Comission 6 (Precast Concrete Comission), with the participation of two brazilians: Prof. Paulo Helene and Iria Lícia Doniak, a study regarding this specific point for the Precast Industry is been developed in the TG 6.15

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fib bulletin 47 - Evironmental Design of Concrete Structures – general principles

- The construction industry differs from the others for its products are not mass produces, have a long service life and high public profile, as this industry is exploring more raw materials and has a more significant energy consumption.

- The quality and quantity of the constructions affect future generations.

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fib bulletin 47 - Evironmental Design of Concrete Structures – general principles

- Sustainable constructions take into account the following considerations:

1. Construction materials which respect the environment,
2. Energetic efficiency and resources consumption,
3. The construction and the management of demolition wastes.

- But the main point is to reduce the use of raw materials.

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fib bulletin 47 - Evironmental Design of Concrete Structures – general principles

- Environmentally a structure can be evaluated using objective indexes (resource, energy, emissions) and average indexes (reduce, reuse, recycle) as environmental performance

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fib bulletin 47 - Evironmental Design of Concrete Structures – general principles

- CLIENT:

The client is the part with greater opportunity to implement environmental objectives. They have authority for decision making and can control the focus on environmental issues.

It is important that the client is aware of the responsibility to assess the environmental and economic benefits in a life cycle perspective.

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fib bulletin 47 - Evironmental Design of Concrete Structures – general principles

- CONCEPTUAL DESIGN:

The most efficient moment to make good decisions is in the first phase of a project, the conceptual design phase.

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Recent standards

- ✓ ACI Committee 130. Sustainability of Concrete
- ✓ U.S. Green Concrete Council. Sustainable Concrete Guide. Strategies and Examples. Applications
- ✓ ISO TC 59/SC 17. Sustainability in Buildings and Civil Engineering Works
- ✓ *ISO 21929-2: Sustainability Indicators (energy, materials, water and land)*
- ✓ ISO TC 207. Environmental Management
- ✓ BS EN 15804:2012+Amendment 1:2013 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products

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Published and under development/revision standards

Published			Under development/Revision	
ISO		CEN	ISO	CEN
Related to Environment Management	**Related to Sustainability of Construction**	**Related to Sustainability of Construction**	**Related to Sustainability of Construction**	**Related to Sustainability of Construction**
14001:2015	15392:2008	15643-1:2010	DIS 15686-5	FprCEN/TR 16970
14004:2016	TS 12720:2014	15643-2:2011	DIS 15686-7	prEN 16757
14040:2006	TS 21929-1:2011	15643-3:2012		
14025:2006	TS 21929-2:2015	15643-4:2012		
14044:2006	21930:2007	15941:2010		
	TS 21931-1:2010	15804:2012 + A1:2013		
	TR 21932:2013	15942:2011		
	15686-1:2011	15978:2011		
	15686-2:2012	16309:2014 + A1:2014		
	15686-3:2002	16627:2015		
	15686-4:2014			
	15686-5:2008			
	15686-7:2006			
	15686-8:2008			
	TS 15686-9:2008			
	15686-10:2010			
	TR 15686-11:2014			

Sustainability of construction works – Environmental product declarations
Product Category Rules for concrete and concrete elements

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Standard: CEN - PREN 16757

SUSTAINABILITY OF CONSTRUCTION WORKS - ENVIRONMENTAL PRODUCT DECLARATIONS - PRODUCT CATEGORY RULES FOR CONCRETE AND CONCRETE ELEMENTS

Scope: This European Standard complements the core rules for the product category of construction products as defined in EN 15804:2012+A1:2013 and is intended to be used in conjunction with that standard.

This European Standard applies to concrete and concrete elements for building and civil engineering.

This document defines the parameters to be reported, what EPD types (and life cycle stages) to be covered, what rules to be followed in order to generate Life Cycle Inventories (LCI) and conduct Life Cycle Impact Assessment (LCIA) and the data quality to be used in the development of EPDs.

In addition to the common parts of EN 15804:2012+A1:2013, this European Standard for concrete and concrete elements:

— defines the system boundaries;

— defines the modelling and assessment of material-specific characteristics;

— defines allocation procedures for multi-output processes along the production chain;

— defines allocation procedures for reuse and recycling; — includes the rules for calculating the LCI and the LCIA underlying the EPD;

— provides guidance/specific rules for the determination of the reference service life (RSL);

— gives guidance on the establishment of default scenarios;

— gives guidance on default functional units for concrete elements.

This document is intended to be used either for cradle to gate, cradle to gate with options or cradle to grave assessment, provided the intentions are properly stated in the system boundary description.

Within the construction works context, a cradle to grave declaration delivers a more comprehensive understanding of the environmental impact associated with concrete and concrete elements.

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Standards / Entities / Groups

- ✓U.S. Green Concrete Council. Sustainable Concrete Guide. Strategies and Examples. Applications (2012)
- ✓EN 15643-1:2010 - Sustainability of construction works - Sustainability assessment of buildings - Part 1: General framework
- ✓EN 15643-2:2011 - Sustainability of construction works - Assessment of buildings - Part 2: Framework for the assessment of environmental performance
- ✓ISO 14000 - Environmental management

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Standards / Entities / Groups

- ✓CEN/TR 15941:2010 - Sustainability of construction works - Environmental product declarations - Methodology for selection and use of generic data
- ✓ISO TC 59/SC 17. Sustainability in Building and Civil Engineering Works (2010)
- ✓ISO TC 71/SC 8. Environmental Management for Concrete and Concrete Structures (2009)
- ✓ISO TC 207. Environmental Management (2009)
- ✓ISO 13315:2011 Environmental Design of Concrete Structures
- ✓ISO 21929:2012 Sustainability Indicators (energy, materials, water and land)

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Recent Standards

Concrete Sustainability. *Forum I, 2009; Forum II, 2010; Forum III, 2011, Forum IV, 2012; Forum V, 2012 and Forum VI, 2013.*
"reduce the volume and reduce CO_2"
"concrete is a regional material, and as shuch should be treated"

ISO TC 71/SC 8. Environmental Management for Concrete and Concrete Structures

ISO 13315-1: General Principles
ISO 13315-2: System Boundary and Inventory Data
ISO 13315-3: Constituents and Concrete Production
ISO 13315-4: Environmental Design of Concrete Structures
ISO 13315-5: Execution of Concrete Structures
ISO 13315-6: Use of Concrete Structures
ISO 13315-7: End of Life including Recycling
ISO 13315-8: Labels and Declaration

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News since "ACI Concrete Sustainability - Forum VI". Phoenix, Arizona, October 2013.

1. Understand the impact of infrastructure and buildings construction to climate change and resource depletion;
2. Understand the opportunities to extend the life of concrete structures using eco-efficient materials incorporating ultra-high performance concrete;
3. Identify innovations that could potentially transform the cement industry, looking for low carbon concrete or, if possible, zero carbon emissions;

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News since "ACI Concrete Sustainability - Forum VI". Phoenix, Arizona, October 2013.

4. Contribute in order that the specifications and design guidelines and construction around the world introduce resources for the effective incorporation of concrete in ecological and sustainable projects

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Also in the United States:

AHPBC American High-Performance Buildings Coalition

Union of 27 associations

Support the development of sustainable buildings and standards

NRMCA

The National Ready Mixed Concrete Asociation

- ✓ *Started the LCA (Life Cycle Assesment) program, complete and embracing*
- ✓ *Introduce the concrete mixes with EPD (Environmental Product Declaration).*
- ✓ *Wishes to increase sales and improve the sector image*

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Redefining High-Performance Concrete Structures

Leo Panian; Phillip Williams; Mike Donovan
Concrete International nov. 2012 p. 23-30

1. Bring aggregates up to 800km away is interesting
2. 70% of slag or fly ash class F
3. Foundations: 55MPa at 91d Content: 119kg/m^3
4. Columns: 55MPa at 91d Content: 133kg/m^3
5. Prestressed slabs: 31MPa at 3d and 41MPa at 56d. Content = 208kg/m^3

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EPD

Enviromental Product Declaration

ISO 14025:2010

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ENVIROMENTAL PRODUCT DECLARATIONS

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What is EPD?

"An EPD® is an certified environmental declaration developed in accordance with the standard ISO 14025:2006" Environmental labels and declarations - Type III environmental declarations - Principles and procedures

The aim of the EPD system is to support the supply and demand for construction products and services that cause less impact to the environment, through the dissemination of production processes, accurate and verifiable data and environmental performance.

This is a document that seeks neutrality and credibility of the products in order to promote sustainable development through the market.

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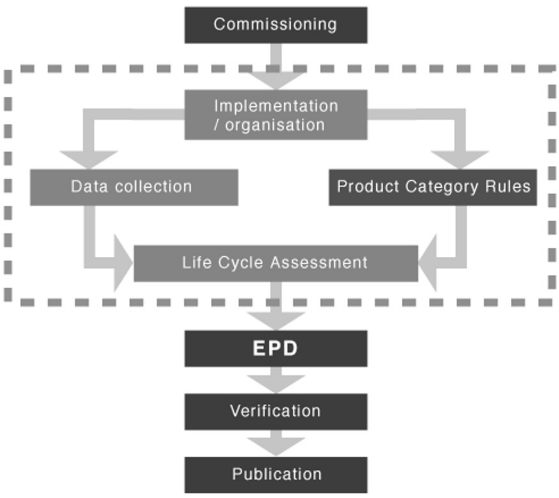
How to elaborate an EPD?



www.greenspec.co.uk

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Therefore, to report the EPD, you must:

- ✓ **Search the available PCRs (*Product Core Rules*), with product specific guidelines analysis (ex: concrete); if it is not available, create the PCR according to ISO 14025:2010**

- ✓ **Collect the necessary data and carry out studies and analyzes of LCA (*Life Cycle Assessment*)**

- ✓ **Request the EPD's verification, made by an auditor of the EPD Program**

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So, the EPD can be validated and inscribed in a certification program (e.g. *International EPD System)*

It will be available for public examination and it is valid for 5 years!

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ECO PLATAFORM

- It is the set of operators, with the aim of developing environmental information verified in construction products, especially EPD's.
- ECO platform members are responsible for continuous improvement of normalizations, assessing quality, best practices and efficient communication of platform informations.

http://www.eco-platform.org/

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ECO PLATAFORM

Consistency	Mutual agreement Common procedures
Reliability	Based on European and International standards Verified scientific approach
Volunteer	Market driven Declaration of values
Transparency	Credible information Full information dossier

http://www.eco-platform.org/

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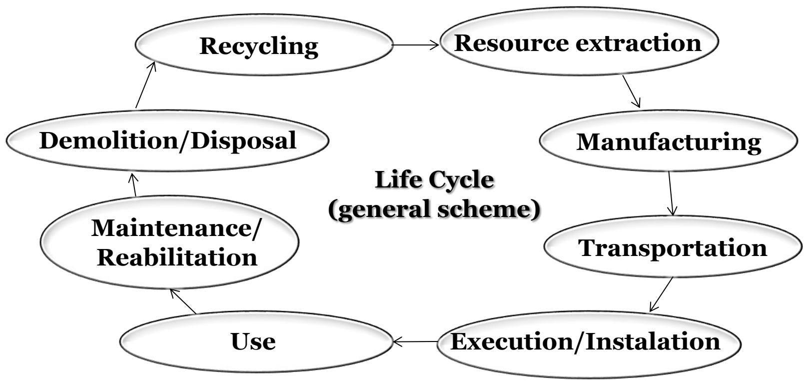
LCA (*Life Cycle Assessment*)

This review shall be made in accordance with the specific product PCR, which will indicate the requirements and minimum life stages to be analyzed



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LCA (*Life Cycle Assessment*)

EN 15804:2012 stablishes a minimum number of stages of the service life to be considered in the EPD;

-EPD1 (Cradle to Gate)

-EPD2 (Cradle to Gate with Options)

-EPD3 (Cradle to Grave)

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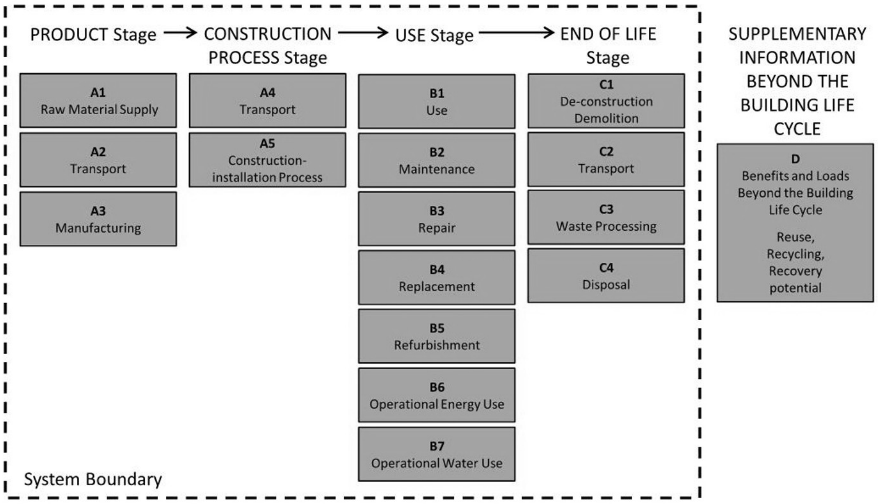

www.coldstreamconsulting.com

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Universidade de Brasília
Departamento de Engenharia Mecânica

ACV

Programa Brasileiro de Avaliação do Ciclo de Vida-PBACV

Armando Caldeira-Pires
Coordenador do CT2-Inventários/PBACV (Prof. UnB)

OFICINA 02: GT CONSTRUÇÃO/CT2/PBACV
Inmetro, 21 de Junho de 2013

Assesment of Life Cycle Brazilian Program

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Universidade de Brasília
Departamento de Engenharia Mecânica

ACV

Projeto Brasileiro
"ICV para a Competitividade da Industria Brasileira"
ICV Brasil

MCT, IBICT, FINEP, Inmetro, INT, UnB, USP, UTFPr,
CNI, SEBRAE, Petrobras, ABCV, Abipti, ABNT

Reuniões Preparatórias: de 2004 a 2006
Início Oficial: Novembro 2006

Coordenação: Instituto Brasileiro para Informação Cientifica e Tecnológica-IBICT/MCT
Apoio: MCT

Fim da Primeira Fase: 2010
Apoio para a 2a. Fase (2010-2012): MCT/MDIC

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Universidade de Brasília
Departamento de Engenharia Mecânica

Programa Brasileiro de Avaliação do Ciclo de Vida - Organograma

ACV

PBACV
- Comitê Gestor
- Comitê de Coordenação
    - Comitês Técnicos
        - CT1 – Captação de Recursos
        - CT2 – Inventários
            - Grupos de Trabalho Setoriais: Gestão de Base de Dados; Construção; Metais, Energia Elétrica, Combustíveis, Agropecuária, Plásticos (Química), Eletroeletronicos (Fim de Vida)
        - CT3 – Avaliação de Impactos Ambientais
        - CT4 – Disseminação
        - CT5 - Capacitação

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The future indicates the LCA, LCIA and LCI

LIFE CYCLE ANALYSIS

"CRADLE TO GRAVE"

Environmental impact indicators:

- Global warming potential, in kg of CO2 equivalent;
- Stratospheric ozone layer depletion potential, in kg of equivalent CFC 11;
- Ground and water acidification potential, in kg of equivalent SO_2;
- Eutrophication potential, in kg of $(PO_4)^{3-}$ equivalent;
- Tropospheric ozone formation potential, in kg of equivalent ethylene;
- Abiotic resources (elements) depletion potential, in kg of equivalent Sb;
- Abiotic resources (fossil fuel) depletion potential, in MJ.

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The future indicates the LCA, LCIA and LCI

LIFE CYCLE ANALYSIS

"CRADLE TO GRAVE"

Life cycle inventories indicators:

- Consumption of non-renewable primary energy, in MJ;
- Renewable primary energy consumption, in MJ;
- The use of non-renewable secondary fuels, in MJ;
- The use of renewable secondary fuels, in MJ;
- Consumption of fresh water, em m^3;
- Production of waste (hazardous, non-hazardous and radioactive), in kg;
- The material for reuse, recycling, energy recovery, in kg.

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Rating and scoring systems for sustainability “the business"

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New Acronyms

- ✓ LCA → Life Cycle Assesment
- ✓ LCI → Life Cycle Inventory Analysis
- ✓ RSL → Reference Service Life
- ✓ EPD → Environmental Product Declaration
- ✓ PCR → Product Category Rules
- ✓ LCIA → Life Cycle Impact Assesment
- ✓ ESL → Estimated Service Life
- ✓ EPDB → Energy Performance of Buildings Directive

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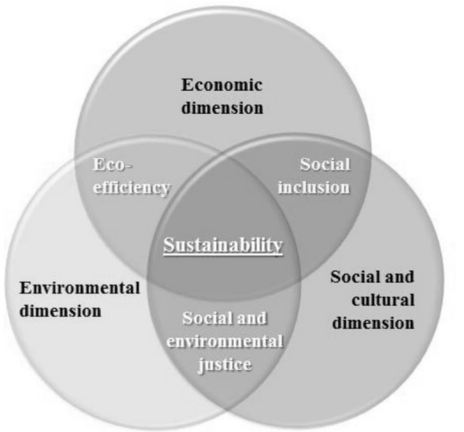
The Sustainable Construction

Tripod of Sustainability



ELKINGTON, J. **Towards the sustainable corporation**: Win-win-win business strategies for sustainable development. California Management Review 36, 2, 90-100, 1994.

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What is LEED?

(Leadership in Energy and Environmental Design) Certification for sustainable buildings created and granted by US NGO U.S. *Green Building Council (USGBC)*. In Brazil this certification is granted by Green Building Council Brazil.

U.S. GREEN BUILDING COUNCIL LEED USGBC®

GREEN BUILDING COUNCIL BRASIL

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LEED

The aim of the system is to reduce the carbon footprint of the built environment and create a competitive system for buildings efficiency by rewarding best practices in design, construction and maintenance, also creating a sustainable market for construction products sector.

The latest version of LEED also includes regional credits which allow tropicalization or adjustment of the system anywhere in the global climate.

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LEED

To be an online documented system certification, but also enabling international growth and adoption of LEED, creating an in fact global standard for sustainable buildings.

It applies to new constructions of commercial or residential buildings, industrial plants, school buildings, existing buildings, focusing on design and construction, interior design, operation and maintenance (use).

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LEED
Leadership in Energy and Environmental Design

This is a scoring system developed by USGBC (United States Green Building Council US) to measure the environmental performance of design, construction and maintenance of buildings.

The system is used to compare the environmental performance of a building and another in the amount of credits from 1-110.

The four levels of accreditation and punctuation are:

Certified → 40-49 credits
Silver → 50-59 credits
Gold → 60-79 credits
Platinum → 80+ credits

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Concrete Thinking for a sustainable world | PCA Portland Cement Association

SOLUTIONS APPLICATIONS RESOURCES CASE STUDIES THINKERS

Benefits > LEED

Green Building Rating System

Print eMail

What is LEED?

Leadership in Energy and Environmental Design (LEED) is a rating system devised by the United States Green Building Council (USGBC) to evaluate the environmental performance of a building and encourage market transformation towards sustainable design. The system is credit-based, allowing projects to earn points for environmentally friendly actions taken during construction and use of a building. LEED was launched in an effort to develop a "consensus-based, market-driven rating system to accelerate the development and implementation of green building practices." The program is not rigidly structured; not every project must meet identical requirements to qualify.

These LEED products are currently available:

- LEED - v3.0 for New Construction and Major Renovations
- LEED - for Homes
- LEED - for Core and Shell
- LEED – for Existing Buildings: Operations and Maintanance
- LEED – for Commercial Interiors
- LEED - for Schools
- LEED - for Retail
- LEED - for Healthcare
- LEED - for Neighborhood Development (in pilot stage)

Detailed information on the LEED program and project certification process is available from USGBC at http://www.usgbc.org/. The program outlines the intent, requirements, technologies, and strategies for meeting each credit. Credits are broken down into individual points. A building requires at least 40 points for certification in LEED-NC v3.0. Silver, gold, and platinum levels are also available.

LEED Certification Levels

- Certified 40 - 49 Points
- Silver 50 - 59 Points
- Gold 60 - 79 Points
- Platinum 80-110 Points

applications

Cast in Place
Controlled Density Fill
Decorative flatwork
Fiber cement siding
Green Roofs
Hardscape & Pavers
ICF (Insulating Concrete Forms)
Masonry
Paving
Pervious Paving
Precast
Radiant Floors
Soil Stabilization/Solidification
Tilt-Up Construction
Water Infrastructure
Whole Building Design

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Heat Island Reduction
Locally Produced
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Thermal Mass

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Submit before Noon, 30 June 2016
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Never before has there been such a focus on healthy sustainable buildings – natural light, fresh air, consistent temperatures and the best possible view to outside are all...
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Supporting Event
[WorldGBC] Asia Pacific Leadership in Green Building Awards for 2016
Supported by the Hong Kong Green Building Council, the Asia Pacific Leadership in Green Building Awards for 2016 will start with its nomination on 18 January 2016.
JAN 18
More >
Announcement
NEW ISSUE
GreenMAG Issue No. 9: Let's Go Shopping in Green Environment
14 Jun 2016
The final issue of GreenMAG talks about "Green Retail Environment" based on our latest research collaboration with the WorldGBC on the report Health, Wellbeing and Productivity in Retail: The Impact of Green Buildings on People and Profit.
More >

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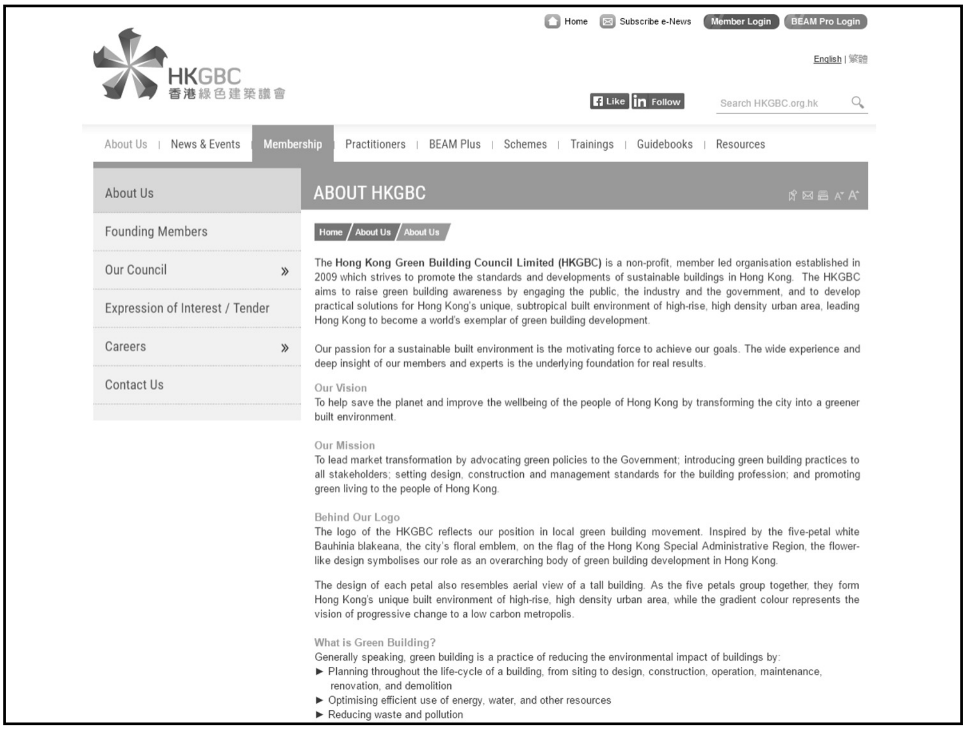
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ABOUT HKGBC
Home / About Us / About Us
The Hong Kong Green Building Council Limited (HKGBC) is a non-profit, member led organisation established in 2009 which strives to promote the standards and developments of sustainable buildings in Hong Kong. The HKGBC aims to raise green building awareness by engaging the public, the industry and the government, and to develop practical solutions for Hong Kong's unique, subtropical built environment of high-rise, high density urban area, leading Hong Kong to become a world's exemplar of green building development.
Our passion for a sustainable built environment is the motivating force to achieve our goals. The wide experience and deep insight of our members and experts is the underlying foundation for real results.
Our Vision
To help save the planet and improve the wellbeing of the people of Hong Kong by transforming the city into a greener built environment.
Our Mission
To lead market transformation by advocating green policies to the Government; introducing green building practices to all stakeholders; setting design, construction and management standards for the building profession; and promoting green living to the people of Hong Kong.
Behind Our Logo
The logo of the HKGBC reflects our position in local green building movement. Inspired by the five-petal white Bauhinia blakeana, the city's floral emblem, on the flag of the Hong Kong Special Administrative Region, the flower-like design symbolises our role as an overarching body of green building development in Hong Kong.
The design of each petal also resembles aerial view of a tall building. As the five petals group together, they form Hong Kong's unique built environment of high-rise, high density urban area, while the gradient colour represents the vision of progressive change to a low carbon metropolis.
What is Green Building?
Generally speaking, green building is a practice of reducing the environmental impact of buildings by:
► Planning throughout the life-cycle of a building, from siting to design, construction, operation, maintenance, renovation, and demolition
► Optimising efficient use of energy, water, and other resources
► Reducing waste and pollution

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Green Building Design & Construction (BD&C)					
Category	**PREVIOUS 2009** LEED-NC v3		**NEW 2013** LEED-NC v4		**CHANGE**
	Prerequisites	Credits	Prerequisites	Credits	
Integrative Process	-	-	-	1	+1 credit
Location and transportation	-	-	-	16	+16 credits
Sustainable Sites	1	26	1	10	-16 credits
Water Efficiency	1	10	3	11	+2 prereq.; +1 credit
Energy & Atmosphere	3	35	4	33	+1 prereq, -2 credits
Materials & Resources	2	14	2	13	-1 credit
Indoor Environmental Quality	3	15	2	16	-1 prereq, +1 credit
Innovation	-	6	-	6	No changes
Regional Priority	-	4	-	4	No changes
Total Points	**10**	**110**	**12**	**110**	

55

How can concrete contribute?

LEED Credit categories in Which Concrete Can Contribute	Points Potentially Influenced by Concrete
Integrative Process	1
Location & Transportation (16 Points Available)	
Neighborhood Development Location	16, or
High Priority Sites	2
Surrounding Density and Diverse Uses	3
Access to Quality Transit	5
Sustainable Sites (10 Points Available)	
Site Development — Protect or Restore Habitat	2
Open Space	1
Rainwater Management	3
Heat Island Reduction	2
Water Efficiency (11 Points Available)	
Outdoor Water Use Reduction	2
Indoor Water Use Reduction	6
Energy & Atmosphere (33 Points Available)	
Minimum Energy Performance	Required
Optimize Energy Performance	18
Material and Resources (13 Points Available)	
Construction and Demolition Waste Management Planning	Required
Building Life-Cycle Impact Reduction	3
Building Product Disclosure and Optimization – Environmental Product Declarations	2
Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
Building Product Disclosure and Optimization – Material Ingredients	2
Construction and Demolition Waste Management	2
Indoor Environmental Quality (16 Points Available)	
Low-Emitting Materials	3
Daylight	3
Quality Views	1
Acoustic Performance	1
Innovation (6 Points Available)	
Innovation	5
LEED AP +	1
Regional Priority (4 Points Available)	4
TOTAL	74

LEMAY, L., PENG, T. Concrete Sustainability Report CSR11. National Ready Mixed Association (NRMCA), Maryland, 2014.

56

High Performance Concretes: a sustainable future

Some LEED certified enterprises in Brazil:

f_{ck} : 50MPa

Use of prestressed concrete to reduce the dimensions of the structure.

Ventura Corporate Towers
Rio de Janeiro/RJ
2011
GOLD

57

High Performance Concretes: a sustainable future

Some LEED certified enterprises in Brazil:

f_{ck} : 50MPa

Eldorado Business Tower
São Paulo/SP
2009
PLATINUM

58

High Performance Concretes: a sustainable future

Some LEED certified enterprises in Brazil:

Reasons for the Platinum:

- ✓ Rational Use of Water
- ✓ Land development
- ✓ Energy efficiency
- ✓ Environmental care with wastes
- ✓ Air conditioning
- ✓ Braking elevators
- ✓ Sustainable materials

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LEED Scorecard	Platinum 46/62
SUSTAINABLE SITES	14 OF 15
WATER EFFICIENCY	4 OF 5
ENERGY & ATMOSPHERE	7 OF 14
MATERIAL & RESOURCES	7 OF 11
INDOOR ENVIRONMENTAL QUALITY	9 OF 12
INNOVATION	5 OF 5

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High Performance Concrete: a sustainable future

Some LEED certified enterprises in Hong Kong/China (102 in total):

	Certification date	City	Country	Rating system	Version	Certification level
NAB Private Wealth HK	21/11/2013	Hong Kong Island	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	Platinum
ABN AMRO Bank N.V., Hong Kong Branch	01/11/2012	Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	Gold
Jones Lang LaSalle	27/07/2011	Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	Platinum
T Rowe Price Hong Kong Expansion	20 May 2016	Central Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	Gold
Yoo Residence		Hong Kong Island	Hong Kong S.A.R., China [hk]	New Construction	v2009	
Manulife Tower Project	16 May 2016	Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	Platinum
TAL Apparel - HK Headquarters Phase 1		Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	
HKU Post-Graduate Residence	14/03/2016	Hong Kong	Hong Kong S.A.R., China [hk]	New Construction	v2009	Silver
1 Hennessy Road		Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	
Wonder 8	29 Oct 2013	Hong Kong	Hong Kong S.A.R., China [HK]	Core and Shell	v2009	Gold
Sha Tin Communications Technology Centre	07/01/2016	Hong Kong	Hong Kong S.A.R., China [hk]	New Construction	v2009	Gold
38-42 Lyndhurst Terrace Development	03/01/2016	Hong Kong	Hong Kong S.A.R., China [hk]	New Construction	v2009	Silver
Grade A Office Development at KTIL761 HK		Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	
Congress Plus	10/11/2015	Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	Gold
Wells Fargo HK Office	27 Sep 2015	Hong Kong SAR	China [cn]	Commercial Interiors	v2009	Gold
Ferrero International S.A.	24 Sep 2015	Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	Gold
Trade and Industry Tower in Kai Tak	22 Sep 2015	Hong Kong	Hong Kong S.A.R., China [hk]	New Construction	v2.2	Platinum
Mapletree Logistics Hub - Tsing Yi		Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	
Redevelopment of Central Mansion		Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	
The Forum Redevelopment	28 Apr 2015	Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	Platinum
88 Sai Yee Street		Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	
3 Macdonnell Road		Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	
Google Hong Kong T2 L25	17 Sep 2015	Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	Certified
HSBC HK International Airport Branch	17 Sep 2015	Hong Kong	Hong Kong S.A.R., China [hk]	Retail - Commercial Interiors	v2009	Certified
Double Cove	16 Sep 2015	Hong Kong	Hong Kong S.A.R., China [hk]	Neighborhood Development plan	v2009	Gold
Sai Kung Hotel		Hong Kong	Hong Kong S.A.R., China [hk]	New Construction	v2009	
LEED EB v4 Test 1.01		Hong Kong	Hong Kong S.A.R., China [hk]	Existing Buildings	v4	
Hotel Indigo (Tai Yuen Street Hong Kong)	29/07/2015	Hong Kong	Hong Kong S.A.R., China [hk]	New Construction	v2.2	Silver
MANNINGS PLUS - HONG KONG IFC MALL	04/06/2015	Hong Kong	Hong Kong S.A.R., China [hk]	Retail - Commercial Interiors	v2009	Gold
Proposed Commercial Development NKIL6512		Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	
HKU Chow Yei Ching Building	23/06/2015	Hong Kong	Hong Kong S.A.R., China [hk]	Existing Buildings	v2009	Gold
113 Argyle Street, Mongkok, Kowloon		Hong Kong	Hong Kong S.A.R., China [hk]	New Construction	v2009	
ITC Causeway Hotel		Hong Kong	Hong Kong S.A.R., China [hk]	New Construction	v2009	
704 -730 Kings Road		Hong Kong	Hong Kong S.A.R., China [hk]	Core and Shell	v2009	
M Moser Hong Kong	14 Oct 2014	Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v4	Silver
LEED CI for SM HSBC Training Centre		Hong Kong	Hong Kong S.A.R., China [hk]	Commercial Interiors	v2009	

http://www.usgbc.org/projects

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High Performance Concrete: a sustainable future

Some LEED certified enterprises in Hong Kong/China

Sha Tin Communications Technology Centre
Hong Kong/China
2016
Gold

http://www.usgbc.org/projects

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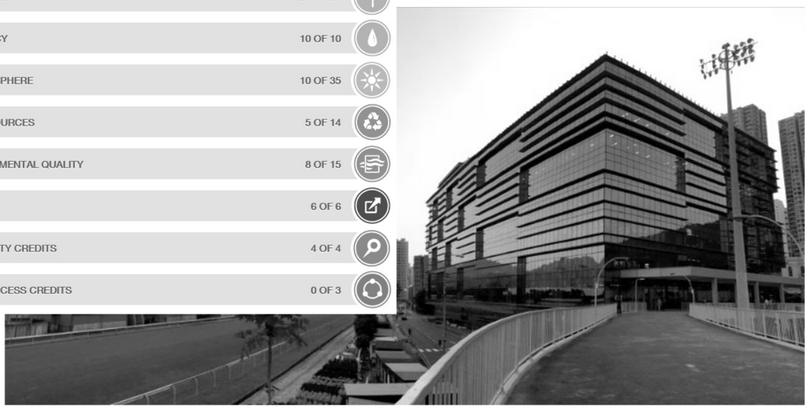
High Performance Concrete: a sustainable future

Some LEED certified enterprises in Hong Kong/China

LEED Scorecard — Gold 66/110

SUSTAINABLE SITES	23 OF 26
WATER EFFICIENCY	10 OF 10
ENERGY & ATMOSPHERE	10 OF 35
MATERIAL & RESOURCES	5 OF 14
INDOOR ENVIRONMENTAL QUALITY	8 OF 15
INNOVATION	6 OF 6
REGIONAL PRIORITY CREDITS	4 OF 4
INTEGRATIVE PROCESS CREDITS	0 OF 3

Reasons for the ***Gold***



http://www.usgbc.org/projects

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High Performance Concrete: a sustainable future

Some LEED certified enterprises in Hong Kong/China

http://www.usgbc.org/projects

U.S. GREEN BUILDING COUNCIL
LEED PLATINUM
USGBC

Trade and Industry Tower in Kai Tak
Hong Kong/China
2015
Platinum

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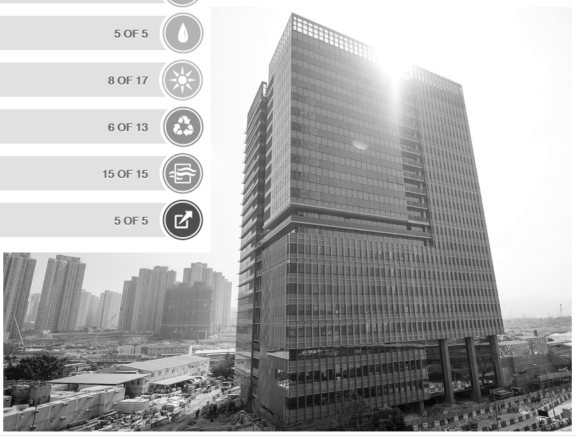
High Performance Concrete: a sustainable future

Some LEED certified enterprises in Hong Kong/China

LEED Scorecard — Platinum 52/69

SUSTAINABLE SITES	13 OF 14
WATER EFFICIENCY	5 OF 5
ENERGY & ATMOSPHERE	8 OF 17
MATERIAL & RESOURCES	6 OF 13
INDOOR ENVIRONMENTAL QUALITY	15 OF 15
INNOVATION	5 OF 5

*Reasons for the **Platinum***



http://www.usgbc.org/projects

65

High Performance Concrete: a sustainable future

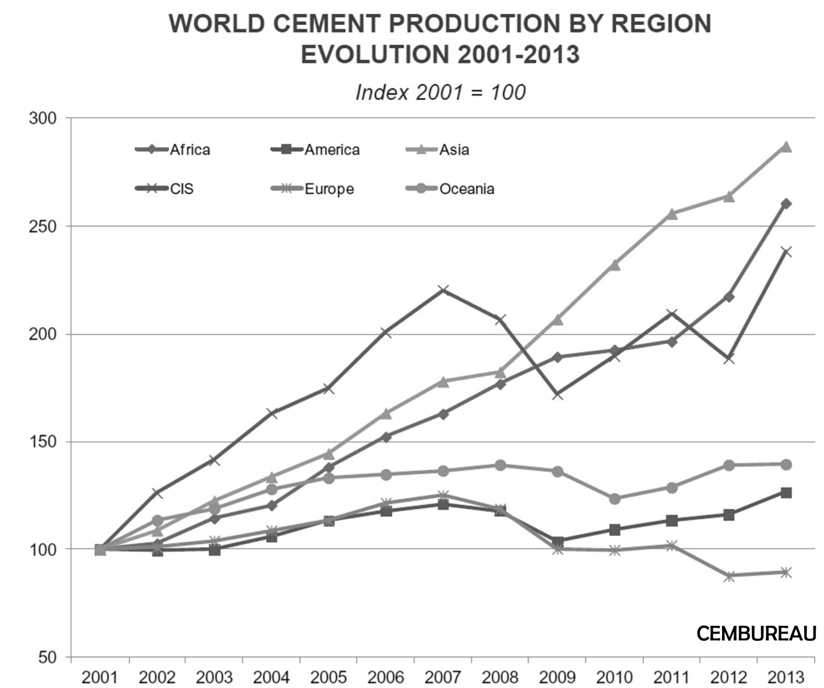
Why does this Programs control much the building use and do not give much relevance to the Materials and Structures?

66

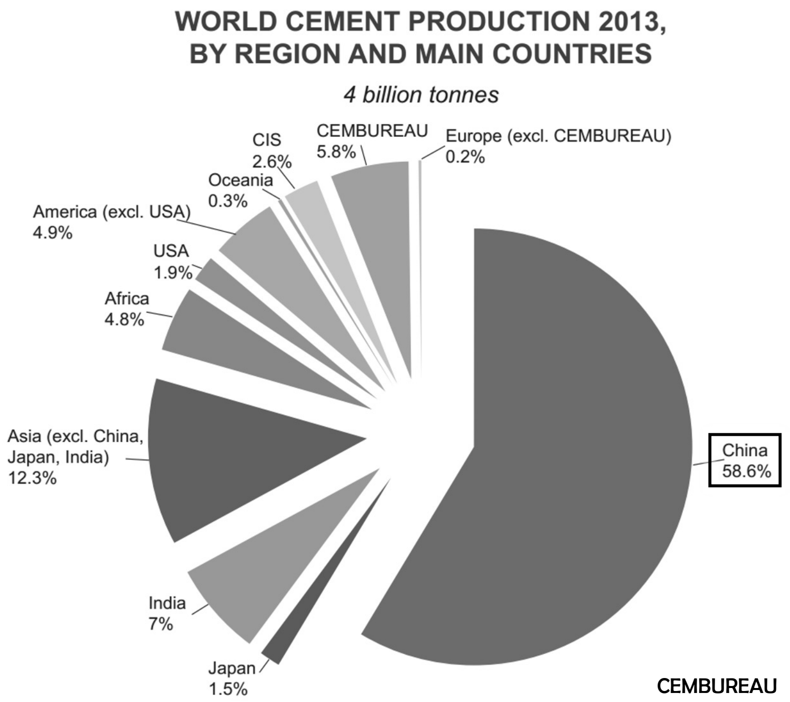
High Performance Concrete: a sustainable future

If the cement is responsible for 6% to 7% of the whole planet's CO_2 emissions, why not to control the concrete from a sustainable point of view?

67



68



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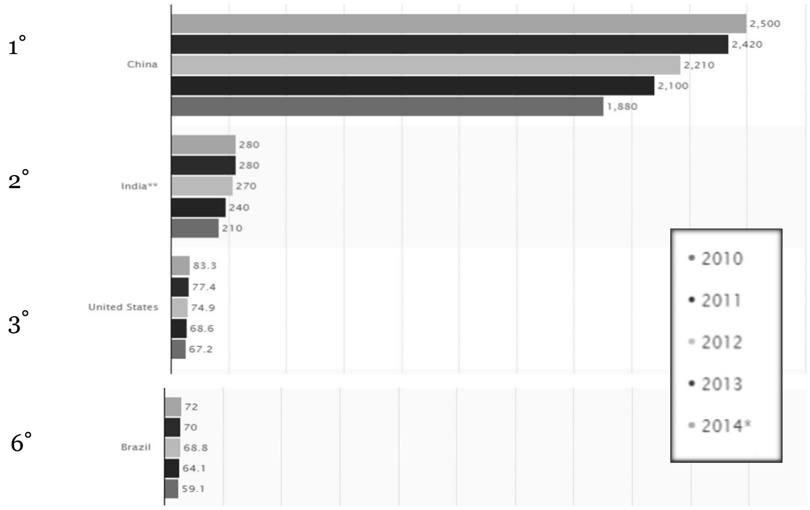
Production capacity

Source: The Global Cement Directory 2013 and work conducted towards publication of the Global Cement Directory 2014

Rank	Company/Group	Country	Capacity (Mt/yr)	No. of plants
1	Anhui Conch	China	217	26
2	Lafarge	France	205	134
3	Holcim	Switzerland	174	117
4	CNBM	China	128	80
5	HeidelbergCement	Germany	90	100
6	Italcementi	Italy	80	60
7	Cemex	Mexico	76	55
8	Taiwan Cement Corp	Taiwan	64	6
9	China Resources	China	59	17
10	Sinoma	China	53	4
11	UltraTech	India	49	23

70

Major countries in worldwide cement production from 2010 to 2014 (in million metric tons)



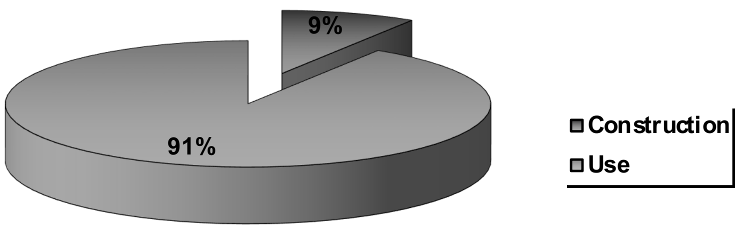
http://www.statista.com/statistics/267364/world-cement-production-by-country/

71

Edification - Emissions of GWP

Considering a service life of 50 years for a middle class house

Holistic Vision: *operation and use*



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CONCLUSIONS

73

- **The cement is not the main villain**
- **The concrete is not banned or unserviceable**
- **Civil engineer of concrete is not reckless or villain**

74

The noble concept of sustainability is beautiful and it has been practiced in concrete structures, which can do even better!

75

Sustainability

"Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs."

United Nations, 1987 - Brundtland Commission

Environmental – Social - Economical

76

How to walk in the direction of SUSTAINABILITY in concrete structures?

77

Options:

1. act on the materials
2. use recycled aggregate
3. use self-compacting concrete (SCC)
4. use high durability concrete
5. use high-strength concrete (HSC)

78

1. Acting on the construction materials:

- cement
- supplementary cementing materials (SMC)
- sand (fine aggregate)
- gravel (coarse aggregate)
- water;
- additives;
- steel / reinforcement;
- formwork

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CEMENT SUSTAINABILITY INITIATIVE (WBCSD – CSI)

World Business Council for Sustainable Development
Cement Sustainability Initiative

- 1999
- 10 international groups
- 25 groups around the world are members of the CSI

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CEMENT SUSTAINABILITY INITIATIVE (WBCSD – CSI)

World Business Council for Sustainable Development
Cement Sustainability Initiative

- In China:

華潤水泥控股有限公司
China Resources Cement Holdings Limited

中国天瑞集团水泥有限公司
China Tianrui Group Cement Company Limited

中国西部水泥有限公司
WEST CHINA CEMENT LIMITED

CNBM China National Building Material Group Corporation

SINOMA 中国中材 China National Materials Group Corporation Ltd.

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CEMENT SUSTAINABILITY INITIATIVE (WBCSD – CSI)

World Business Council for Sustainable Development
Cement Sustainability Initiative

- In Brazil:

Votorantim Cimentos

LIZ CIMENTOS

InterCement

LAFARGE Holcim

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HOW TO MITIGATE CO_2 EMISSIONS?

World Business Council for Sustainable Development
Cement Sustainability Initiative

- Energy efficiency
- Alternative fuels
- Cement additives
- Carbon capture and imprisonment

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ALTERNATIVE FUELS

World Business Council for Sustainable Development
Cement Sustainability Initiative

According to WBCSD – CSI, in the study"Getting the Numbers Right" (GNR):

"Brazil is the leader in the use of biomass as substitute fuel, with 12% of total thermal energy generated. Adding 9% fossil waste, Brazil also replaces more than one fifth of fossil fuels with alternative fuels".

84

Recent investigations in Brazil

85

Nanotubes and Carbon Fibers:

A way for the sustainability of cementitious materials

SOUZA, T. C. C.; SUZUKI, S.; LUDVIG, P.; CALIXTO, J. M.; LADEIRA, L. O. **CONCRETO & CONSTRUÇÕES.** São Paulo: Ibracon, jan. 2015. Trimestral.

Use of NTC and NFC in order to increase the strength and reduce the concrete pores.

86

Nanotecnology: NTC and NFC adplied directly to Clinker particles

- Results:

Increased durability by refinement of the pores in hydrated cement paste (20% reduction in pore diameter).

Increased setting time of up to 17%

Clinker content reduction for the same resistance by increasing the strength of concrete up to 21%.

87

Yesterday Concrete: Tomorrow Cement:

The use of concrete wastes in Clinker production

NOBRE, T. R. S.; GUERREIRO, A. Q.; KIRCHHEIM, A. P.

CONCRETO & CONSTRUÇÕES. São Paulo: Ibracon, jan. 2015. Trimestral.

Objective: Evaluate the possibility of using concrete and other industrial wastes as raw meal composition of Portland cement.

88

Results of the Processing

- ✓ Environmental benefit;
- ✓ Economic factor;
- ✓ Innovation in Clinker production;
- ✓ Closure of the life cycle;
- ✓ Contains all the needed minerals which make up the raw material;
- ✓ Composite simple emits less CO_2 tan pure sample.

VIABLE !

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High Performance Concrete: a sustainable future

2. Use of concrete with recycled aggregate from the wastes generated by new construction or demolition

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Pergamon
Available online at www.sciencedirect.com
SCIENCE DIRECT®
Cement and Concrete Research 34 (2004) 1975–1980
CEMENT AND CONCRETE RESEARCH

Durability of recycled aggregates concrete:
a safe way to sustainable development

Salomon M. Levy[a,b], Paulo Helene[b,c,d,*]

[a] *Centro Universitário Nove de Julho (UNINOVE), São Paulo, Brazil*
[b] *Brazilian Concrete Institute (IBRACON), São Paulo, Brazil*
[c] *Polytechnic School, University of São Paulo, São Paulo, Brazil*
[d] *Rehabilitar Network CYTED XV.F, Madrid, Spain*

Received 18 March 2003; accepted 10 February 2004

Concrete made with recycled aggregates (20%, 50%, and 100% replacement) from old masonry or from old concrete can have the **same fresh workability** and can achieve the **same compressive strength** of concrete made by natural aggregates in the range of 20–40 MPa at 28 days.

Referenced by 210 articles - Google Scholar

91

Recycled Aggregate

- Recycled of cementitious base (concrete and mortars)
- Recycled of ceramic base (floors, masonry)
- Replace them from 20% to 50% of the fine and coarse aggregate without affecting strength and durability

92

Sustainability **2010**, *2*, 1204-1225; doi:10.3390/su2051204

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

Recycled Concrete as Aggregate for Structural Concrete Production

Mirjana Malešev [1], Vlastimir Radonjanin [1] and Snežana Marinković [2,*]

[1] Department for Civil Engineering, Faculty of Technical Sciences, Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia; E-Mails: miram@uns.ac.rs (M.M.); radonv@uns.ac.rs (V.R.)

[2] Faculty of Civil Engineering, University of Belgrade, Bul. kralja Aleksandra 73, 11000 Belgrade, Serbia

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“Recycled concrete aggregate was produced by crushing of “old” concrete cubes used for compressive strength testing and one precast reinforcedo concrete column, which had inappropiate dimensios. [...]
The strength class of old concrete cubes was **C30/37** and the corresponding value of compressive strength for precast column was **C40/50** [...]”

Concrete compressive strength mainly depends on the quality of recycled aggregate. If good quality aggregate (obtained by crushing higher strength class concrete as in this case) is used for the production of new concrete, the recycled aggregate has no influence on the compressive strength, regardless of the replacement ratio of natural coarse aggregate with recycled aggregate. The same conclusion is valid for concrete tensile strength (splitting and flexural).

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High Performance Concrete:
a sustainable future

3. use high performance

self-compacting concrete (SCC)

95

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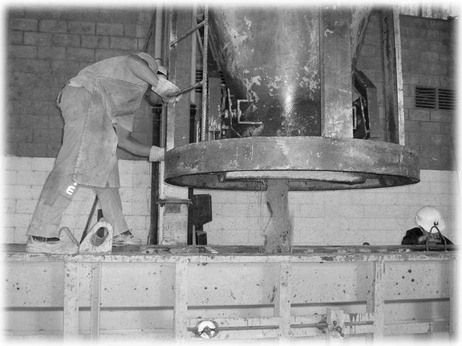
Comparative study



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self-compacting concrete (SCC)

vibrated concrete

98

10 x productivity

Vibrated concrete:
placed and finished: 4.4min + 3.3min
n. of workers: 5 (five)
placing (2), vibrating (1) and finishing (2)

0.870 man-hour / m³ of concrete

SCC:
Placed and finished: 1.2min
n. of workers: 3 (three)
placing (1) and finishing (2)

0.081 man-hour / m³ of concrete

99

100

SCC

1. Reduces noise → health
2. Reduces time → productivity
3. Increases uniformity
4. Reduces electric energy → do not use vibrator
5. Reduces formwork wear
6. Enhances service life

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High Performance Concrete: a sustainable future

4. use high durability concrete

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Carbonation

e = 2,0 cm

f_{ck}= 15 MPa → t = 8 years

f_{ck}= 25 MPa → t = 38 years

f_{ck}= 50 MPa → t = 240 years

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Centro Empresarial Nações Unidas - Torre Norte
São Paulo - 1997
179 m high
f_{ck} = 50MPa

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Environmental Impact Assessment Review 31 (2011) 253–260

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

ELSEVIER

Life cycle CO_2 evaluation on reinforced concrete structures with high-strength concrete

Sungho Tae, Cheonghoon Baek *, Sungwoo Shin

Hanyang University School of Architecture & Architectural Engineering 1271, Sa 3-dong, Sangrok-gu, Ansan, Gyeonggi-do, 426-791 Korea

The target building for evaluation is a tall apartment building made of reinforced concrete with a total floor area of 14,424 m_2, 35 stories above the ground

Table 7
Re-design of high-strength concrete.

	Previous design	Re-design of high-strength concrete
27–top	24 MPa	40 MPa
20–26 stories	27 MPa	40 MPa
10–19 stories	30 MPa	40 MPa
1–9 stories	35 MPa	40 MPa

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Case 1: demolition and reconstruction after 50years
Case 2: maintenance after 50 years
Case 3: 100years service life due to the use of high strength concrete (redesign)

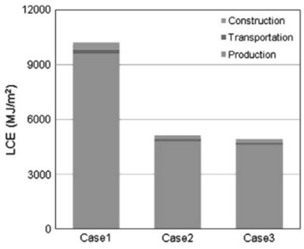

Fig. 4. Energy consumption for construction stage.

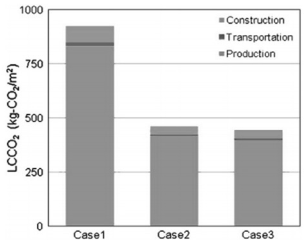

Fig. 5. CO_2 emission for construction stage.

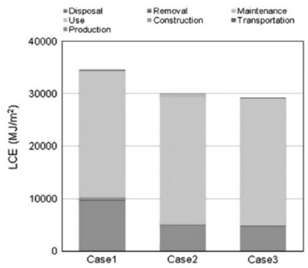

Fig. 6. Energy consumption for building life cycle.

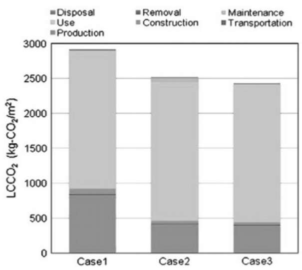

Fig. 7. CO_2 emission for building life cycle.

In particular, the energy consumption of case 3 for <u>construction stage</u> **decreased 51.89% and 3.79%** respectively compared with case 1 and case 2, and the evaluation of CO2 emission also **decreased 52.06% and 4.12%** respectively compared with case 1 and case 2.
The energy consumption of case 3 for <u>life cycle</u> **decreased 15.53% and 2.95%** respectively compared with case 1 and case 2, and CO2 emission also **decreased 16.70% and 3.37%** respectively compared with case 1 and case 2.

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Sustainable Development, Global Change and Ecosystems

Sustainable Surface Transport

ARCHES

Strategic Targeted Research Project

ARCHES

Assessment and Rehabilitation of Central European Highway Structures

Deliverable D14

RECOMMENDATIONS FOR THE USE OF UHPFRC IN COMPOSITE STRUCTURAL MEMBERS

REHABILITATION LOG ČEZSOŠKI BRIDGE

108

Recommendations for the Use of UHPFRC in Composite Structural Members e Rehabilitation Log Čezsoški Bridge.
Deliverable ARCHES D14.
Denarié, E., Habert, G., Sajna, A., 2009.

"Four systems are compared: two **traditional rehabilitation systems** and two **rehabilitation systems using UHPFRC**. The difference between the two solutions in the same system is the nature of the binder used. We have made a distinction between a standard solution where CEM I is the only binder that is used and an "eco-solution" where 50% of mineral addition is substituted to cement. [...]"

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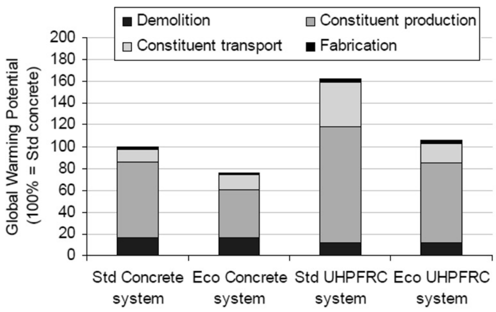
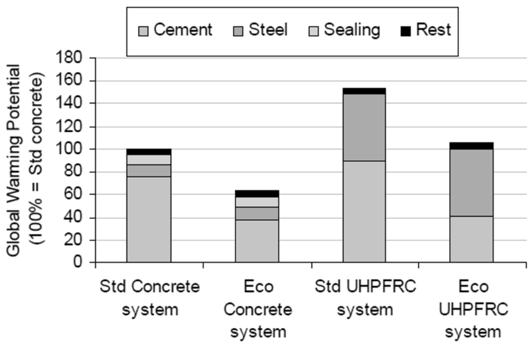


"[...] while considering the **construction phase only**, no environmental improvements were observed between a traditional rehabilitation system and the UHPFRC system"

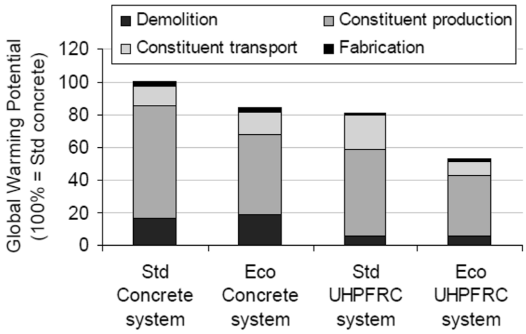
but...



110

"If it is assumed that the **durability** of a traditional solution is 30 years, the durability of eco-concrete can be set at 80% of that **and the durability of both UHPFRC can be assumed to be at least twice longer**. To compare the impact of the different solutions, it should then be assumed that one will need 2 rehabilitations with traditional systems while we will do a single rehabilitation with UHPFRC systems"

Rehabilitation systems with UHPFRC have then **much lower impact** than both traditional rehabilitation systems.



When the rehabilitation lifespan was considered, a CO_2 emissions reduction of close to 50% could be achieved

Sustainable Development

"Increasing service life of concrete structures we can preserve the natural resources.

If we develop the design and construction ability we can get concrete structures with 500 years service life. Doing this we can multiply by ten our productivity which means preserve the 90% of them"

Kumar Mehta
Reducing the Environmental Impact of Concrete
Concrete International. ACI, v.23, n. 10, Oct. 2001. p.61-66

High Performance Concrete:
a sustainable future

5. use high-strength concrete (HSC)

113

High Performance Concrete:
a sustainable future

- **CO_2?**
- **Energy?**
- **Natural resources?**
- **Life cycle?**

114

High Performance Concrete: a sustainable future

Column for 500t

f_{ck} = 20MPa

f_{ck} = 50 MPa

115

Considering a typical central column of a 20-story building, square cross section, 3m high, main reinforcement

Characteristic normal strength= 500 tf			
f_{ck} (MPa)	steel rate (%) → total of the column	cross section (cm)	adopted (cm)
20	0.4 → 49kg	71.8 x 71.8	72 x 72
50	0.4 → 24kg	46.9 x 46.9	50 x 50
20	4.0 → 255kg	51.2 x 51.2	52 x 52
50	4.0 → 151kg	39.5 x 39.5	40 x 40

116

High Performance Concrete:
a sustainable future

f_{ck} = 20MPa

Cement = 280 kg/m³
Sand = 845 kg/m³
Gravel = 1036 kg/m³
Water = 210 kg/m³

117

High Performance Concrete:
a sustainable future

f_{ck} = 50MPa

Cement = 420 kg/m³
Sand = 801 kg/m³
Gravel = 1010 kg/m³
Water = 160 kg/m³

118

Trace Gas	GWP	Trace Gas	GWP
Carbon Dioxide	1	HFC-143a	3800
CCl 4	1300	HFC-152a	140
CFC- 11	3400	HFC-227ea	2900
CFC-113	4500	HFC-23	9800
CFC-116	>6200	HFC-236fa	6300
CFC-12	7100	HFC-245ca	560
CFC-l 14	7000	HFC-32	650
CFC-l 15	7000	HFC-41	150
Chloroform	4	HFC-43-lOmee	1,300
HCFC- 123	90	Methane	21
HCFC- 124	430	Methylenechloride	9
HCFC-141b	580	Nitrous Oxide	310
HCFC-142b	1600	Perfluorobutane	7000
HCFC-22	1600	Perfluorocyclobutane	8700
HFC- 125	2800	Perfluoroethane	9200
HFC-134	1,000	Sulphur hexafluoride	23900
HFC-134a	1300	Trifluoroiodomethane	<1
HFC-143	300		

119

Gaseous emissions and energy consumption

Material	NOx (kg/t)	CO_2 (kg/t)	GWP (kg/t)	Energy consumed (kWh/t)
Portland Clinker (≈ CP I)	1.85	855	1447 (880)	998
Pig iron (mineral) CA 50 & CA 60 (waste)	4.43	1588 380	3006 719	5,060 20,000

**Global warming potential (GWP) is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the gas in question to that of the same mass of carbon dioxide.*

120

Structural Concrete
f_{ck} 20MPa

	1 m^3	GWP kg/t	GWP kg/m^3	Energy kWh/m^3
Cement CP I	280kg	1447	405	280
Sand	845kg	0	0	1
Gravel	1036kg	0	0	12
Water	210kg	0	0	0
Steel CA50 & CA60	32kg 315kg	719	23 226	640 6300
Formwork 12 m^2/m^3 6 reuses 1.4cm plate	0,0280 m^2	0	0	43
TOTAL			**428** **631**	**933** **6636**

121

Structural concrete
f_{ck} 50MPa

	1 m^3	GWP kg/t	GWP kg/m^3	Energy kWh/m^3
Cement CP I	420kg	1447	607	419
Sand	801kg	0	0	3
Gravel	1010kg	0	0	12
Water	160kg	0	0	0
Steel CA50 & CA60	32kg 315kg	719	23 226	640 6300
Formwork 12 m^2/m^3 6 reuses 1.4cm plate	0,0280 m^2	0	0	43
TOTAL			**630** **833**	**1117** **6777**

122

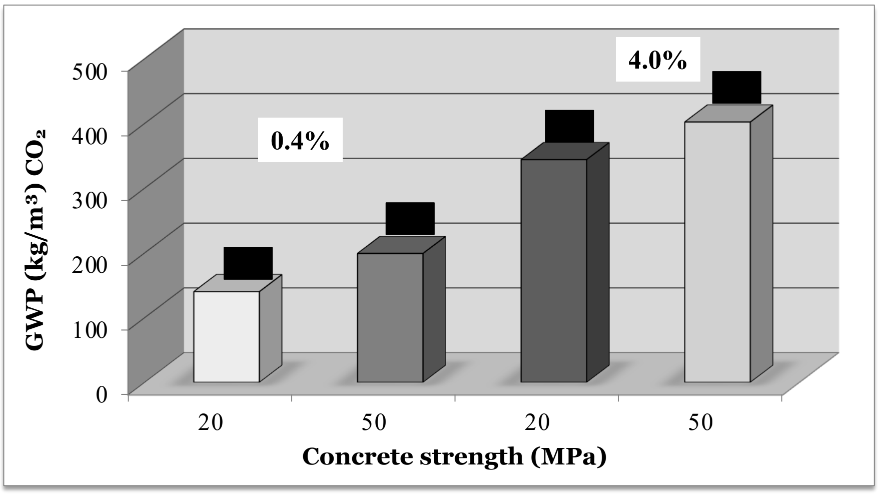
1 m³ of structural concrete

Material	Type	f_{ck}	GWP	Energy
		MPa	kg/m³	kWh/m³
Reinforced concrete	CP I	20	428 / 631	933 / 6636
Reinforced concrete	CP III	20	140 / 344	777 / 6437
Reinforced concrete	CP I	50	630 / 833	1117 / 6777
Reinforced concrete	CP III	50	199 / 402	820 / 6480

0.4% & 4%
steel rate

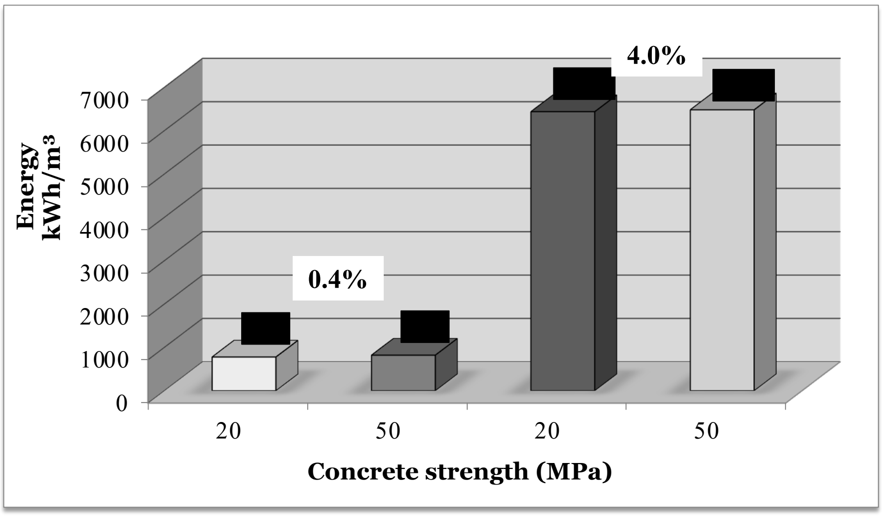
123

1 m³ of structural concrete with 70% slag



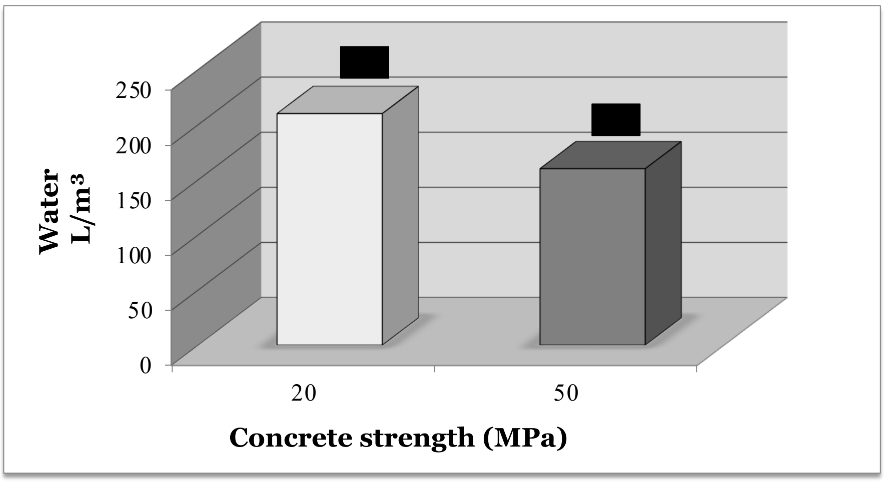
124

1 m³ of structural concrete



125

1 m³ of structural concrete



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Column 3m high, 0.4% steel rate, 500tf

Material	f_{ck}	cross section	energy	GWP
	MPa	cm	kWh	kg
Reinforced concrete	20	72x72	1208	218
Reinforced concrete	50	50x50	615	149

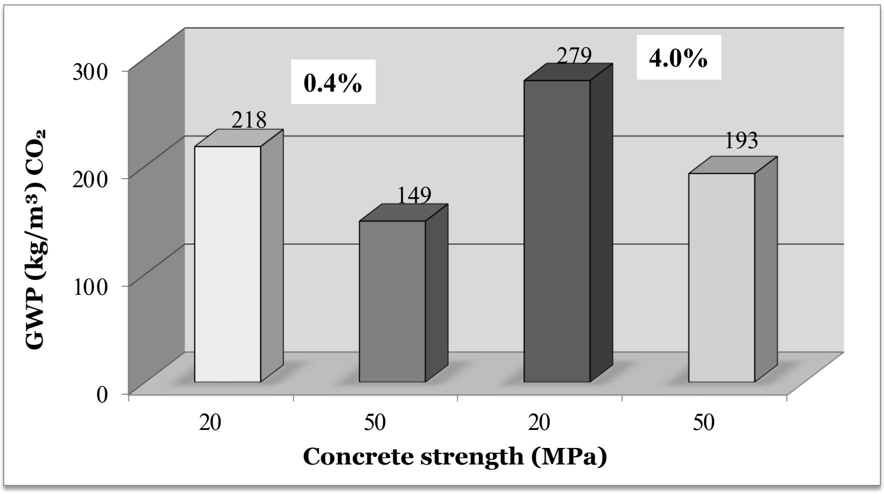
127

Column 3m high, 0.4% steel rate, 500tf

Material	f_{ck}	cross section	energy	GWP
	MPa	cm	kWh	kg
Reinforced concrete	20	52x52	5221	279
Reinforced concrete	50	40x40	3110	193

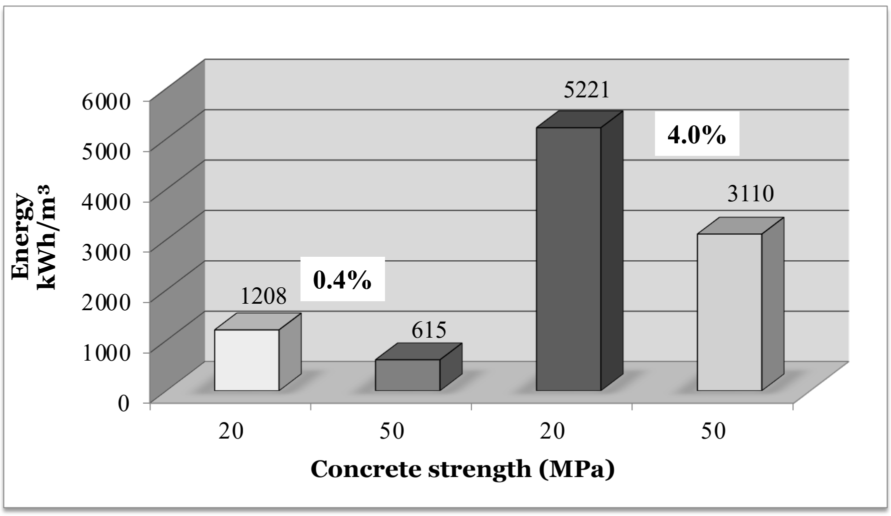
128

Column 3m high, square cross section, 500tf



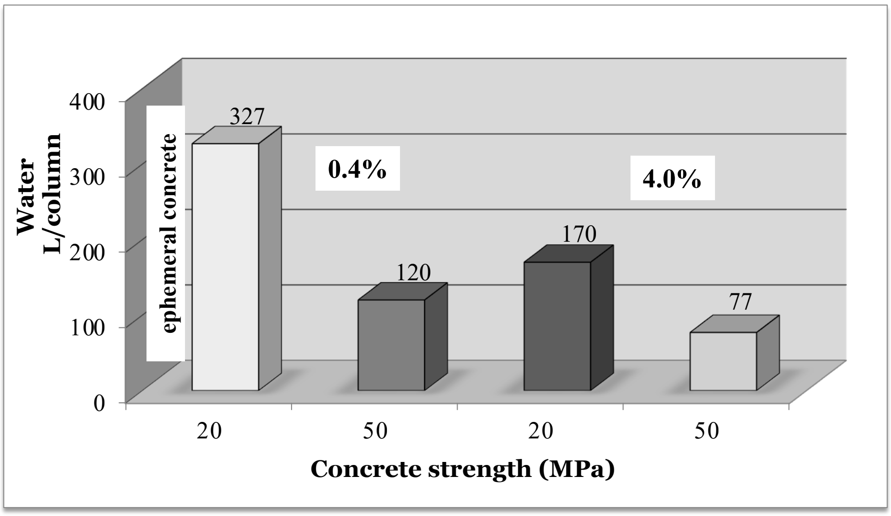
129

Column 3m high, square cross section, 500tf



130

Column 3m high, square cross section, 500tf



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High Performance Concrete: a sustainable future

Investigation:

Which is the most sustainable concrete?

f_{ck} = 25MPa (250kgf/cm²)

f_{ck} = 30MPa (300kgf/cm²)

f_{ck} = 35MPa (350 kgf/cm²)

132

Investigation: reinforced concrete building

- Low level;
- 8 storeys type;
- coverage, stairs and upper reservoir

Comparative analysis:

- 25 MPa;
- 30 MPa, keeping the same dimensions of the structural elements of 25 MPa;
- 35MPa, reducing the dimensions of structural elements.

Obtained structural area was of 2,078 m^2.
Load: 0.55 tf/ m^2 (permanent load + live load).

133

Investigation: reinforced concrete building

25 MPa :

Cement: 310 kg
Sand: 870 kg = 0,53 m^3 sand / m^3 concrete
Gravel: 930 kg = 0,52 m^3 gravel / m^3 concrete
Water: 180 kg (or litters)

30 MPa :

Cement: 340 kg
Sand: 770 kg = 0,47 m^3 sand / m^3 concrete
Gravel: 970 kg = 0,54 m^3 gravel / m^3 concrete
Water: 180 kg (or litters)

35 MPa :

Cement: 370 kg
Sand: 744 kg = 0,45 m^3 sand / m^3 concrete
Gravel: 960 kg = 0,53 m^3 gravel / m^3 concrete
Water: 180 kg (or litters)

134

Investigation: reinforced concrete building
Materials amount

Para 25MPa :

concrete	formwork	steel
471 m^3	4596 m^2	41619 kg
0.23 m^3/m^2	2.20 m^2/m^2	20.0 kg/m^2
		88.0 kg/m^3

Para 30MPa :

concrete	formwork	steel
471 m^3	4596 m^2	40130 kg
0.23 m^3/m^2	2.20 m^2/m^2	19.3 kg/m^2
		85.1 kg/m^3

Para 35MPa :

concrete	formwork	steel
401 m^3	4464 m^2	39596 kg
0.19 m^3/m^2	2.10 m^2/m^2	19.1 kg/m^2
		98.7 kg/m^3

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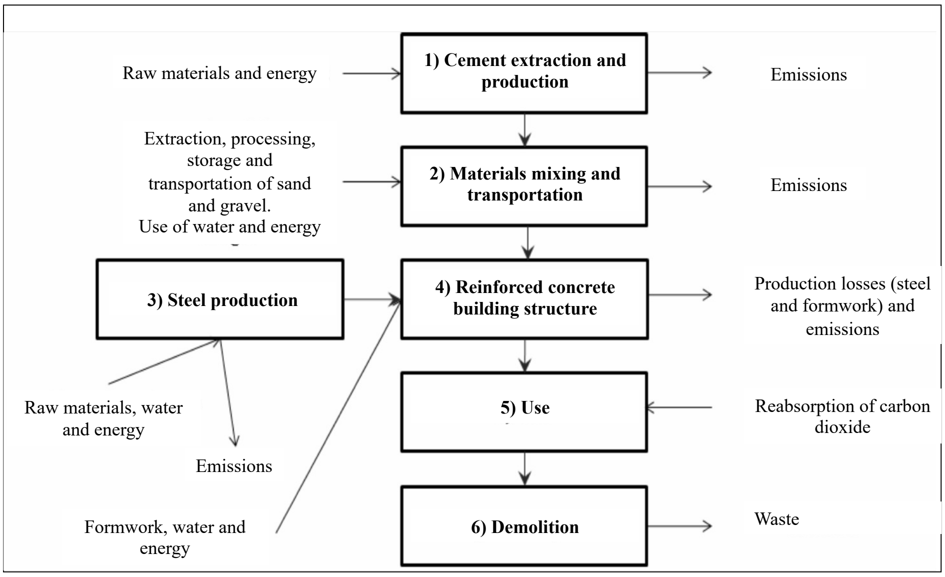
Investigation: reinforced concrete building

Product flow diagram→ ...from cradle to grave...



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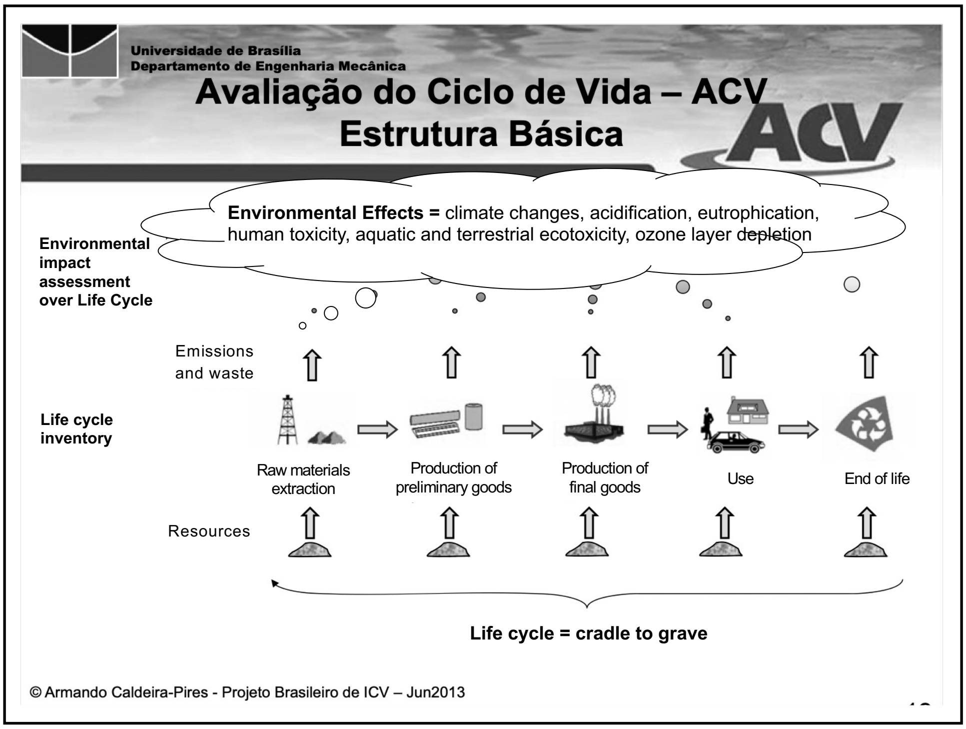

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RESEARCH REPORT R11-01, **Methods, Impacts, and Opportunities in the Concrete Building Life Cycle**, Department of Civil and Environmental Engineering,Concrete Sustainable Hub, Massachusetts Institute of Technology, august, 2011.

ILCD handbook **– International reference Life Cycle Data System; General guide for Life Cycle Assessment – Detailed guidance**, Publications Office of the European Union, 2012, 394 p.

ISO 14025:2006
Environmental labels and declarations - Type III environmental declarations - Principles and procedures

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Reinforced concrete

… from cradle to grave…

	Category	Unit	Total	Materials	Production	Transport	End of Life
	Global warming	[g CO_2-eq.]	102 610.0	67 800.0	27 700.0	3 720.0	3 390.0
	Acidification	[g SO_2-eq.]	836.6	535.0	266.0	35.3	0.3
	Eutrophication	[g NO_3-eq.]	712.2	471.0	179.0	59.2	3.0
	Photochemical smog	[g C_2H_4-eq.]	24.2	18.0	0.8	4.6	0.7

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Investigation: reinforced concrete building

The results obtained in relation to the impacts were studied:

	25 MPa	30 MPa	35 MPa
Eutrophication	Greater	Medium	Minor
Photochemical ozone formation	Greater	Medium	Minor
Material resources consumption	Greater	Medium	Minor
Energetic resources consumprion	Greater	Medium	Minor
Ecotoxicity	Greater	Medium	Minor
Global Warmig	Medium	Greater	Minor
Human toxicity	Greater	Medium	Minor
Acidification	Medium	Greater	Minor
Wastes	Medium	Greater	Minor

Ricardo BENTO, doutorado IAU.USP.

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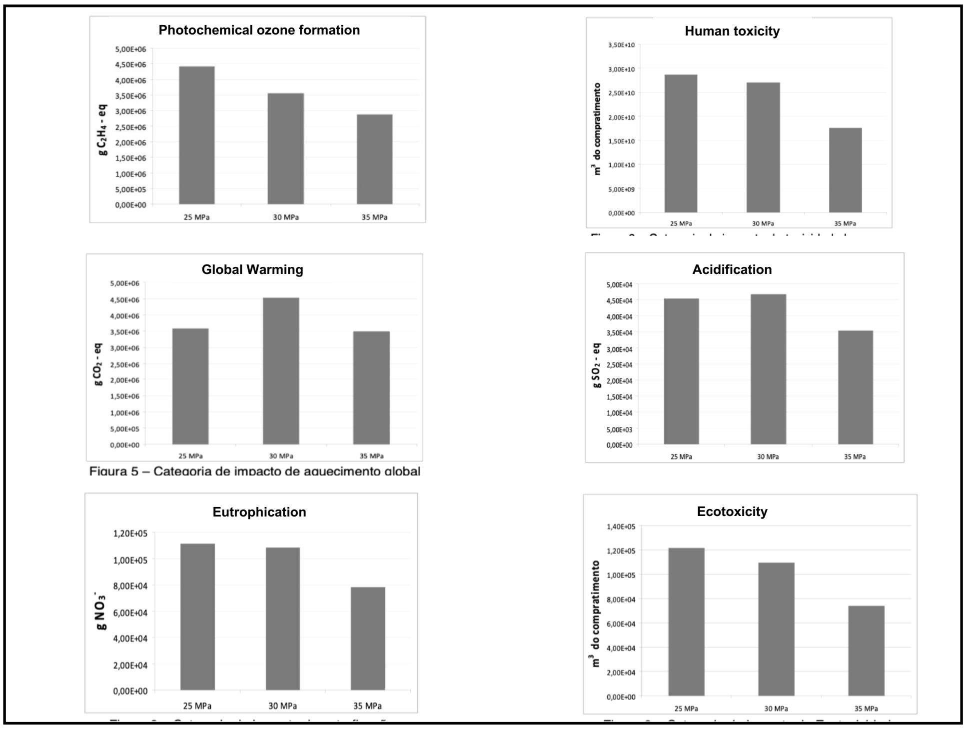
Photochemical ozone formation
g C2H4 - eq
25 MPa
30 MPa
35 MPa
Human toxicity
m3 do comprimento
Global Warming
g CO2 - eq
Figura 5 – Categoria de impacto de aquecimento global
Acidification
g SO2 - eq
Eutrophication
g NO3-
Ecotoxicity
m3 do comprimento

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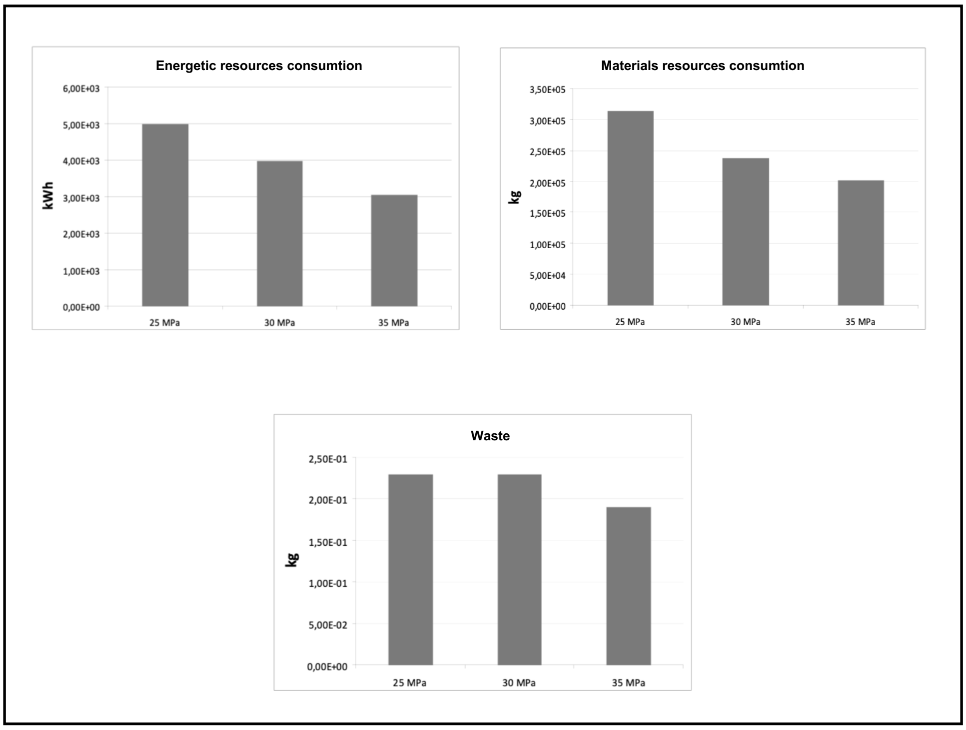
Energetic resources consumtion
kWh
6,00E+03
5,00E+03
4,00E+03
3,00E+03
2,00E+03
1,00E+03
0,00E+00
25 MPa
30 MPa
35 MPa
Materials resources consumtion
kg
3,50E+05
3,00E+05
2,50E+05
2,00E+05
1,50E+05
1,00E+05
5,00E+04
0,00E+00
Waste
kg
2,50E-01
2,00E-01
1,50E-01
1,00E-01
5,00E-02
0,00E+00

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Investigation: reinforced concrete building

This is an investigation of Eng. Ricardo Bento and it is part of his Doctoral thesis, that is still ongoing (on progress)

"Even though the work is not fully completed it is already possible to say that there was a clear advantage in replacing concrete 20MPa for 35MPa in a low middle class building with just 8 floors.“

“The studies in progress will analyze other situations, houses and high buildings (> 25 floors) to verify that this partial findings, but very promising, can be generalized, and for the development of high performance concrete (high performance)”

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Investigation: reinforced concrete building

Conclusion:

For all the environmental impact categories, the 35MPa structure has the minimum values, performing the same function, then the 30MPa structure and, finally, the 25MPa structure

Ricardo BENTO, doutorado IAU.USP.

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sustainability

MDPI

Article

Analysis of CO_2 Emission Characteristics of Concrete Used at Construction Sites

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[2] Building Project Operation Division, GS Engineering & Construction, Gran Seoul 33, Jongro, Jongro-Gu, Seoul 03159, Korea; khkim6@gsconst.co.kr

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Column design change

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Column design change

Original design: 30 MPa + SRC structure
ALT 1: 45 MPa, concrete only
ALT 2: 50 MPa, concrete only

Table 7. Material fluctuation according to pillar strength change.

Category		Original Plan	ALT 1	ALT 2
Concrete (m^3)	30 MPa	1532	525	-
	45 MPa	-	1007	1007
	50 MPa	-	-	430
Rebar (ton)	SD40	199	-	
	SD50	-	589	618
Steel-frame	SM49	747	-	-

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Table 9. CO_2 emission difference according to pillar change [Unit: kg-CO_2].

Category		Original Plan	ALT 1	ALT 2
Concrete	30 MPa	519,930	178,174	-
	45 MPa	-	299,985	299,985
	50 MPa	-		132,788
Rebar	SD40	877	-	-
	SD50	-	2597	2725
Steel-frame	SM49	3869	-	-
Total		524,676	480,756	435,495
Reduction ratio (%)		-	15%	23%

The CO_2 emission reduction method at the construction stage can be summarized as the application of high-strength concrete, the standardization of reduction mix design using blast-furnace slag, and the selection of RMC companies with low CO_2 emission.

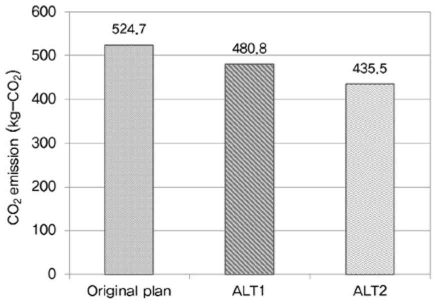

Figure 7. Comparison of CO_2 emission according to pillar change.

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These tools clearly stablished at ISO14025 environmental series allow the creation of a type III declaration, or allow an objective qualification of the products and services to construction.

In this way, it is developed a transparency of the products in relation to its environmental impacts.

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The revolution which is underway from these concepts uses a standardized methodology for data collection, environmental impact assessment, access to homogenized information and continued review of the environmental performance of products and services.

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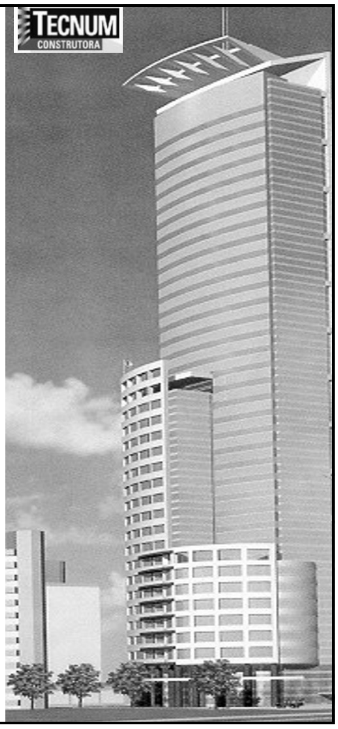
e-Tower

- e-Tower building / SP
- 42 floors
- Heliport
- semi-Olympic pool
- Gym
- 2 restaurants
- colored concrete
- f_{ck} columns = 80MPa



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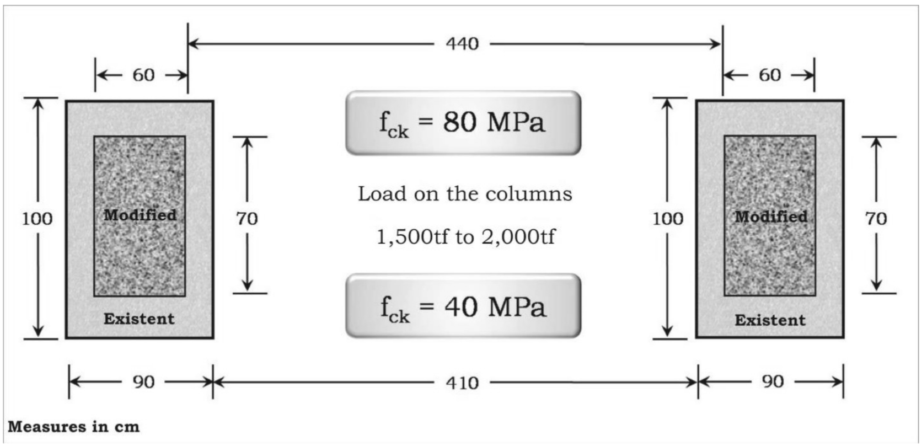
Structural design (e-Tower)



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Myth

HSC > 125MPa

consumes much cement and is not sustainable

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TRUTH

it may consume more cement per m^3, but the amounts of CO_2 , energy and water greatly reduces with high strength

CO_2 / MPa

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Control

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Natural Resources Economy

Original:

f_{ck} = 40MPa

Cross section→ 90cm x 100cm → 0,90m²

HPC / HSC:

f_{ck} = 80MPa

Cross section→ 60cm x 70cm → 0,42m²

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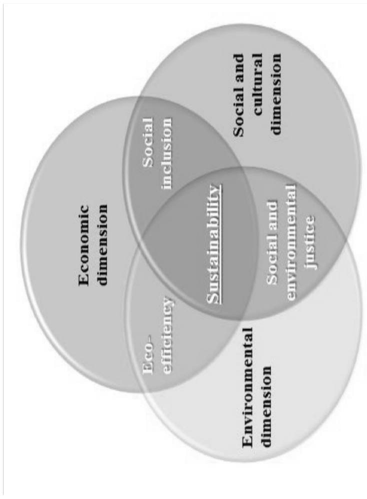
Sustainability



- 70% less sand
- 70% less gravel
- 53% less concrete
- 53% less water
- 20% less cement
- 31% less formwork area

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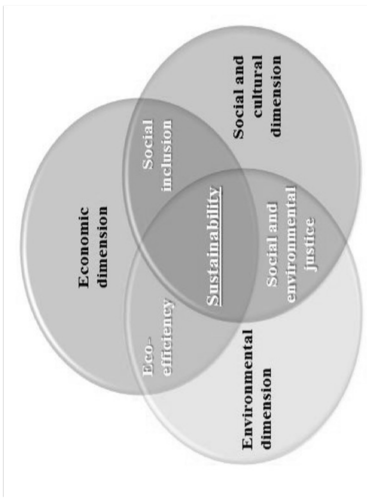
Sustainability



- 25% more reuse of formwork
- 43% less steel
- 16 more parking lots
- 10x greater service life
- 100% faster formwork removal

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Journal of Cleaner Production 35 (2012) 250–262

Contents lists available at SciVerse ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

ELSEVIER

Cleaner Production

Reducing environmental impact by increasing the strength of concrete: quantification of the improvement to concrete bridges

Guillaume Habert[a,*], David Arribe[b], Thibault Dehove[b], Ludovic Espinasse[b], Robert Le Roy[c,d]

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[b] Ecole des Ponts ParisTech, 6 – 8 av. Blaise Pascal Cité Descartes, Champs-sur-Marne 77455, Marne-La-Vallée, France
[c] National High School of Architecture, 14 rue Bonaparte, 75272 Paris Cedex 06, France
[d] Univ Paris-Est, laboratoire Navier (ENPC/IFSTTAR/CNRS, UMR 8205), 6 – 8 Avenue Blaise-Pascal, 77455 Marne-la-Vallée cedex 2, France

Compares the environmental impacts of 2 existing classic bridges, made to cross a four-lane divided highway with a two-lane road

- ***The 1st one made by traditional concrete***
- ***The 2nd one constructed with high performance concrete***

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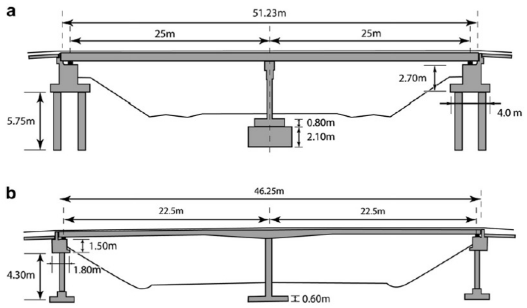

Fig. 1. Longitudinal cross-section of the bridge constructed with a) traditional concrete or b) high performance concrete.

(a) Traditional concrete bridge (Saône et Loire, 71 – France)
Two 25m-long spans for a total length of 51.53m

(b) High performance concrete bridge (Bourges, Cher, 18 – France)
Two 22.5m-long spans for a total length of 46.25m

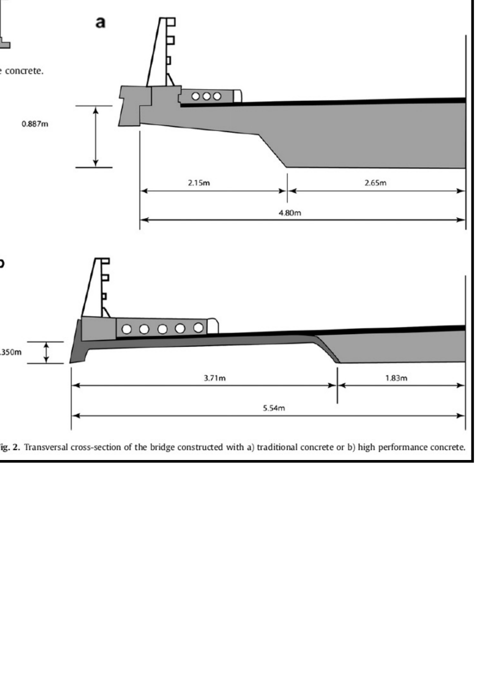

Fig. 2. Transversal cross-section of the bridge constructed with a) traditional concrete or b) high performance concrete.

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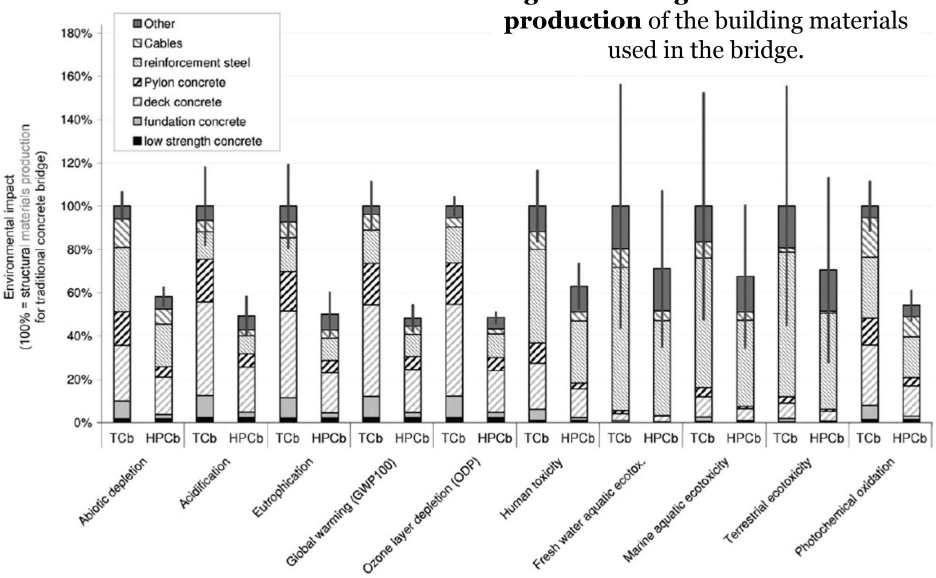
TCb = Traditional Concrete bridge
HPCb = High Performance Concrete bridge

The present study shows that the use of high performance concrete allows for **a 50% reduction in greenhouse gas emissions for production** of the building materials used in the bridge.



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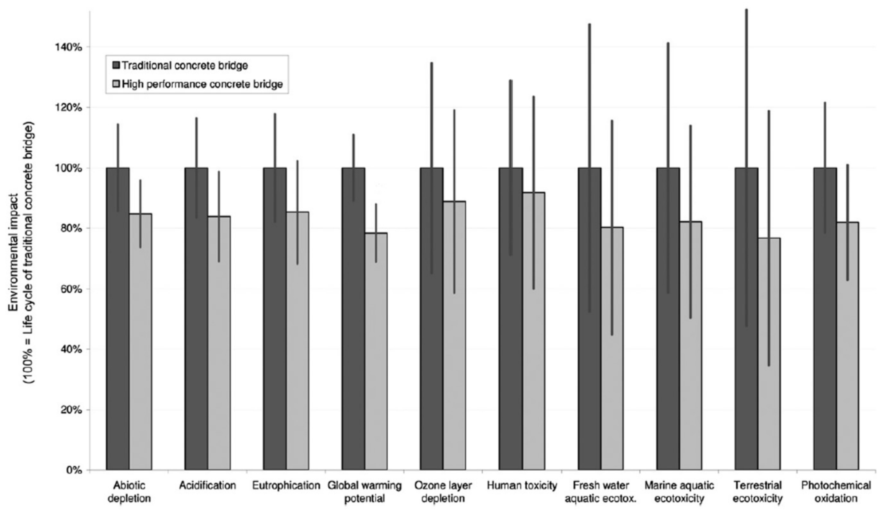
[…] **the HPC bridge design yields savings of approximately 15% for all impact categories** […] except for those dealing with ecotoxicity. For ecotoxicity, the HPC bridge solution allows **savings of 20%** […].



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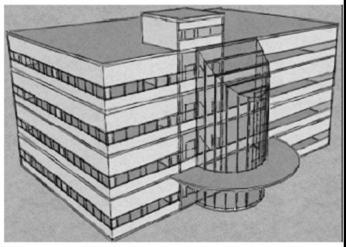
37th Conference on Our World in Concrete and Structures
29-31 August 2012, Singapore

IMPROVING SUSTAINABILITY OF CONCRETE CONSTRUCTION – THE ROLE OF HIGH STRENGTH AND HIGH PERFORMANCE CONCRETE

Per Fidjestol and Rein Terje Thorstensen

Elkem as Silicon Materials, Fiskaaveien, 4675 Kristiansand, Norway.
PH +47 380 17509, FAX +47 280 14970, email: per.fidjestol@elkem.no



Compares design solutions for the same building, in terms of CO_2, cost and service life in a chloride exposure.
Four solutions were studied:

- Conventional structure: (B35)
- High-strength Concrete (HSC): 85 MPa, developed using particle packing model on local materials (B85)
- Different structural floor solutions were used for each concrete strength (conventional deck and flat slab bubbledeck)

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Table 9. Summary of results

	Building 1	Building 2	Building 3	Building 4
	Conv.	HSC	Conv.	HSC
	Conv deck	Conv. deck	Bubbledeck Bubble	Bubble Bubbledeck Bubble
Total CO_2 [tonnes]	532.2	353.6	380.2	242,3
CO_2 Saving	0	33.6	28.6	54.5
Total cost NOK	5 787 558	6 616 858	5 173 032	4 993 661
Service life (years)	52.9	206+	52.9	206+

"This example has shown that by using HSC/HPC in the chosen buildings, together with structural measures, it should possible to achieve **more than 50% reduction in total construction CO_2** emissions."

"...In the longer term, the use of high strength HPC will give even larger benefits in terms of **long service life**, reduced maintenance because of durable structure and lastly the benefits of having an all-concrete, heavy structure that will reduce the total energy needed to modify the climate of the structure."

DURABILITY

Chloride resistance (NTBUILD 492[12]) (Also AASHTO TP64)

The chloride resistance of this high strength concrete was excellent: Transport coefficient determined using Nordtest NT BUILD 492:

HSC (Mixture 11): $0.48 \cdot 10^{-12}$ m^2/sec
Conventional concrete (C45): $8,18 \cdot 10^{-12}$ m^2/sec

These values were then used to estimate service life in a chloride environment Life365 default).

Table 10. Estimated service life in chloride environment (default environment)

LIFE365™ 2.01[13]	Conventional concrete	HSC
Service life (years) using default exposure	52,9	206+ (the maximum the software would determine)

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Environ. Res. Lett. **10** (2015) 114017 doi:10.1088/1748-9326/10/11/114017

Environmental Research Letters

LETTER

Greenhouse gas emissions from concrete can be reduced by using mix proportions, geometric aspects, and age as design factors

Sabbie A Miller, Arpad Horvath, Paulo J M Monteiro and Claudia P Ostertag
Department of Civil and Environmental Engineering, 745 Davis Hall, University of California, Berkeley, CA 94720-1710, USA
E-mail: sabbiemiller@gmail.com

Investigates the influence of **design age**, in addition to **mix proportions** and **geometric aspects**, on the GWP associated with 4 different functional units:

1. Cubic meter of concrete
2. Beam
3. Column
4. Concrete building frame

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Studied concrete mixes proportions

Name	w/b (kg/kg)	%FA (%)	Cement content (kg m^{-3})	Fly ash content (kg m^{-3})	Water content (kg m^{-3})	Fine aggregate content (kg m^{-3})	Coarse aggregate content (kg m^{-3})	Superplastizer content (kg m^{-3})
Mix 1 1-0	1.00	0%	200	0	200	846	1060	0
Mix 2 0.71-0	0.71	0%	273	0	195	732	1116	0
Mix 3 0.56-0	0.56	0%	351	0	195	670	1147	0
Mix 4 0.45-0	0.45	0%	425	0	193	607	1122	0
Mix 5 0.38-0	0.38	0%	507	0	195	565	1096	0
Mix 6 0.71-0.57	0.71	57%	106	141	176	696	1180	0
Mix 7 0.56-0.67	0.56	67%	106	211	176	624	1168	0
Mix 8 0.45-0.73	0.45	73%	108	288	180	562	1126	1.3
Mix 9 0.38-0.77	0.38	77%	106	352	176	524	1099	3.3
Mix 10 0.71-0.29	0.71	29%	180	72	180	721	1166	0
Mix 11 0.56-0.44	0.56	44%	176	141	176	650	1191	0
Mix 12 0.45-0.55	0.45	55%	180	216	180	577	1136	0
Mix 13 0.38-0.62	0.38	62%	180	288	180	531	1097	2.1
Mix 14 0.33-0.67	0.33	67%	180	360	180	490	1052	3.8
Mix 15 0.56-0.22	0.56	22%	246	70	176	660	1174	0
Mix 16 0.45-0.36	0.45	36%	252	144	180	593	1147	0
Mix 17 0.38-0.46	0.38	46%	252	216	180	544	1110	1.7
Mix 18 0.33-0.53	0.33	53%	246	282	176	509	1082	4.2
Mix 19 0.29-0.59	0.29	59%	252	360	180	465	1017	7.2
Mix 20 0.45-0.18	0.45	18%	324	72	180	611	1155	1
Mix 21 0.38-0.31	0.38	31%	324	144	180	558	1122	2.1
Mix 22 0.33-0.40	0.33	40%	317	211	176	520	1096	3.6
Mix 23 0.29-0.47	0.29	47%	317	282	176	484	1048	8
Mix 24 0.38-0.15	0.38	15%	396	72	180	572	1135	3
Mix 25 0.33-0.27	0.33	27%	387	141	176	534	1108	4

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Studied concrete mixes compressive strengths

Name	w/b (kg/kg)	%FA (%)	Compressive strength (MPa)			
			14 days	28 days	56 days	112 days
Mix 1 1-0	1.00	0%	10.6	12.2	12.6	12.8
Mix 2 0.71-0	0.71	0%	22.7	24.7	28.5	30.1
Mix 3 0.56-0	0.56	0%	30.5	35.5	36.4	39.7
Mix 4 0.45-0	0.45	0%	41.9	45.0	49.2	51.2
Mix 5 0.38-0	0.38	0%	53.8	56.4	63.3	65.9
Mix 6 0.71-0.57	0.71	57%	6.6	7.7	9.0	12.7
Mix 7 0.56-0.67	0.56	67%	7.0	8.4	10.0	13.5
Mix 8 0.45-0.73	0.45	73%	8.8	11.1	13.6	19.3
Mix 9 0.38-0.77	0.38	77%	7.8	9.3	13.9	18.0
Mix 10 0.71-0.29	0.71	29%	13.4	15.9	18.0	22.0
Mix 11 0.56-0.44	0.56	44%	18.6	22.0	25.6	32.1
Mix 12 0.45-0.55	0.45	55%	18.0	23.3	29.2	34.9
Mix 13 0.38-0.62	0.38	62%	17.9	21.8	23.8	34.8
Mix 14 0.33-0.67	0.33	67%	19.4	25.5	30.2	39.2
Mix 15 0.56-0.22	0.56	22%	26.7	30.0	34.3	41.0
Mix 16 0.45-0.36	0.45	36%	24.1	29.2	35.0	46.1
Mix 17 0.38-0.46	0.38	46%	27.0	32.4	38.1	46.5
Mix 18 0.33-0.53	0.33	53%	24.5	28.3	35.9	43.2
Mix 19 0.29-0.59	0.29	59%	34.0	40.6	48.7	54.1
Mix 20 0.45-0.18	0.45	18%	36.1	44.0	48.6	56.3
Mix 21 0.38-0.31	0.38	31%	38.0	41.3	48.5	54.8
Mix 22 0.33-0.40	0.33	40%	50.1	54.0	60.0	73.7
Mix 23 0.29-0.47	0.29	47%	42.0	46.5	58.2	66.6
Mix 24 0.38-0.15	0.38	15%	44.2	48.9	52.3	61.9
Mix 25 0.33-0.27	0.33	27%	40.0	49.3	55.4	63.3

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1. Cubic meter functional unit

Using low levels of binder and especially low levels of cement would result in the lowest possible GWP. However, mechanical properties and changes in strength development differ based upon changes in binder and cement content.

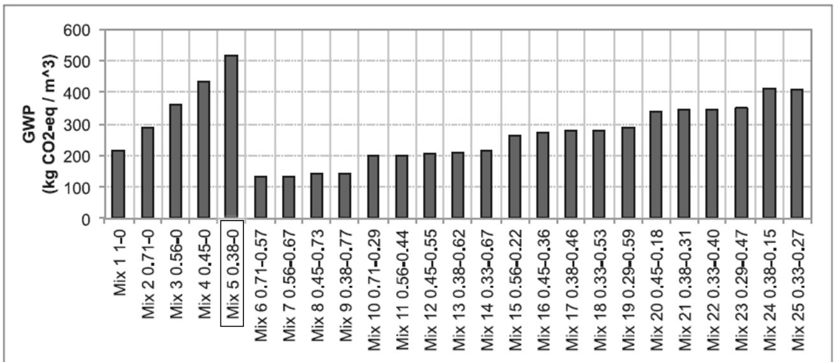

Figure 1. Global warming potential comparison based on cubic meter functional unit where mixtures are referred to by number, w/b ratio, and percent fly ash (for example, Mix 15 0.56-0.22 represents mix number 15 with a w/b ratio of 0.56 and 22% fly ash).

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2. Beam functional unit

Increased age and the influence of strength development do not play a significant role in reducing GWP for the beam design functional unit. This is a reflection of the reinforcement playing a larger role in the member design than the concrete strength.

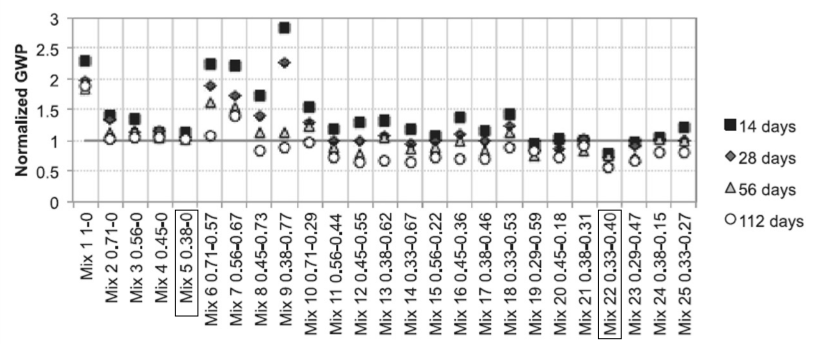

Figure 2. Comparison of concrete mixtures using beam functional units for design ages normalized to being designed with the US average concrete mixture with mean compressive strength of 30 MPa 28 days. Concrete mixtures are referred to by number, w/b ratio, and percent fly ash (for example, Mix 15 0.56-0.22 represents mix number 15 with a w/b ratio of 0.56 and 22% fly ash).

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3. Column functional unit

Notably, **the highest cement content concretes**, which have a high GWP on a cubic meter functional unit basis of comparison, **have among the most favorable GWP for the column design** at 28 days.
The attributes of low w/b ratio and high cement content typically are associated with high GWP concretes, but **in the case where strength can contribute significantly to the volume of material needed, the high associated GWP per cubic meter of material can be outweighed**.

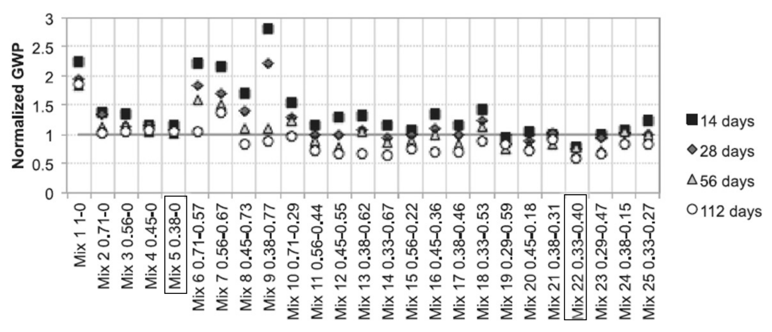

Figure 3. Comparison of concrete mixtures using column functional units at for design ages normalized to being designed with the US average concrete mixture with a mean compressive strength of 30 MPa 28 days. Concrete mixtures are referred to by number, w/b ratio, and percent fly ash (for example, Mix 15 0.56-0.22 represents mix number 15 with a w/b ratio of 0.56 and 22% fly ash).

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4. Concrete building frame functional unit

Table 3. Parameters investigated for improvements to concrete building frame.

Nomenclature	Definition
Baseline	Represents use of a concrete mixture with the US average fly ash use (22%) and 30 MPa compressive strength
Mix change (all)	Represents use of concrete mixtures that have the lowest GWP while meeting the specified strength (30 MPa)
Mix change (columns)	Represents use of the lowest GWP concrete mixtures that have the required strength for each column level
Geometric change (columns)	Represents reduction in volume of concrete used for columns at higher floor levels
Columns (both)	Represents a combination of two previous column changes
Combination	Represents a combination of all previous changes

Combining all methods, including using the lowest GWP concrete mixture with appropriate strength, column design methods, and strength development, results in a **potential 44% reduction of GWP for the concrete frame relative to designing at 28 days** with the US average FA replacements.
Based on the mixtures examined in this analysis, **use of the lowest-GWP concrete with appropriate strength for the building design at the highest design age has approximately 40% lower GWP** than the baseline mixture.

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4. Concrete building frame functional unit

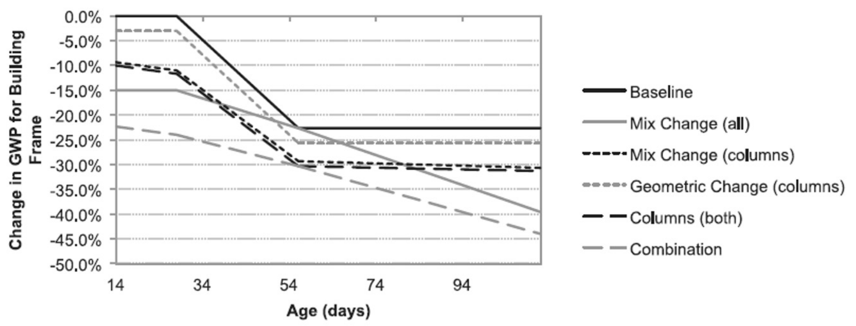

Figure 4. Comparison of design alternatives for a concrete frame: percent change reflects the difference in GWP for each design alternative relative to designing the entire concrete frame with the US average concrete mixture with 30 MPa strength at 28 days. The 'baseline' alternative represents use of concrete mixtures that have the US average FA replacement of OPC with at least 30 MPa compressive strength at the specified ages. The 'mix change (all)' alternative represents use of concrete mixtures that possess at least 30 MPa compressive strength at the specified ages with the lowest GWP. The 'mix change (columns)' alternative represents use of the lowest GWP concrete mixtures that have the required strength for each column level. The 'geometric change (columns) alternative represents reduction in volume of concrete used for columns at higher floor levels. The 'columns (both)' alternative represents a combination of the two previous column changes. The final alternative represents a combination of all previous alternatives.

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CONCLUSIONS

- Constant volume comparisons do not adequately portray differences in GWP for structural members
- Incorporation of material properties and application are necessary for adequate comparisons of concrete mixtures
- Strength development and the different rates of strength development of concrete mixtures influence the ability to use certain concrete mixtures for a set application. Use of alternative concrete mixtures that require less cement can be achieved if higher design ages are specified, thus reducing associated GWP.

From these results, it is clear that **the influence of design requirements and strength development can play a large role in the GWP associated with materials for construction of structures: up to 40% reduction** for the building frame analyzed in this research.

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Important points

***Yield* concept:**

Considering only cement content:

Concrete 120MPa → 4,0kg/MPa
→ 1,2kg clinker / MPa

Concrete 40MPa → 6,7 kg/MPa
→ 2,1kg clinker / MPa

Concrete 20MPa → 11,5 kg/MPa
→ 3,5kg clinker / MPa

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Materials Revolution!

1972	2016
cement / sand / gravel / water	cement / sand / gravel / water
slag	slag
fly ash	fly ash
plasticizer	plasticizer
	super plasticizer
	setting regulator
	fibers
	metakaolin HP
	silica fume
	nano silica
	pigments
	crystallizing / nanotube
	densifier / limestone

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RESPONSIBLE, SUSTAINABLE, BEAUTIFUL AND CONTEMPORANEOUS CONCRETE IS:

→ stronger

→ more durable

→ more human (< noise and < physical effort)

→ consumes less non-renewable material resources

→ consumes less water

→ consumes less energy

→ produces less waste and garbage

178

Other points for which concrete contributes

The use of energy in buildings accounts for a large share of the total end use of energy in Europe (40%).
Concrete's thermal mass can be used to avoid or reduce temperature swings in the building and to eradicate the need for energy guzzling air conditioning systems. Concrete stores heat in the winter and cools buildings in the summer, creating optimum comfort conditions for the occupants. Dense, heavyweight concrete provides the highest amount of thermal mass. Research results demonstrate that buildings with high levels of thermal mass, passive solar features and effective ventilation controls perform extremely well as regards energy efficiency.
Sustainable benefits of concrete structures. European Concrete Platform ASBL, February 2009

For buildings, where the climate is of importance, the ability of heavy materials, like concrete or stone, to accumulate heat and to release it will encompass a saving in heating and cooling of up to 10 or 20%, something which has a huge impact on the accumulated energy consumption of a building
IMPROVING SUSTAINABILITY OF CONCRETE CONSTRUCTION – THE ROLE OF HIGH STRENGTH AND HIGH PERFORMANCE CONCRETE
Per Fidjesto - Elkem as Silicon Materials, Norway
Rein Terje Thorstensen, Elkem as Silicon Materials, Norway
37th Conference on OUR WORLD IN CONCRETE & STRUCTURES: 29 - 31 August 2012, Singapore

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How to be a better and prevailing Architect or Engineer?

1. reduce greenhouse gas emissions
2. reduce energy consumption
3. reduce consumption of non-renewable natural resources
4. use the concrete rationally (do more with less)
5. change the "way of life“ of some people

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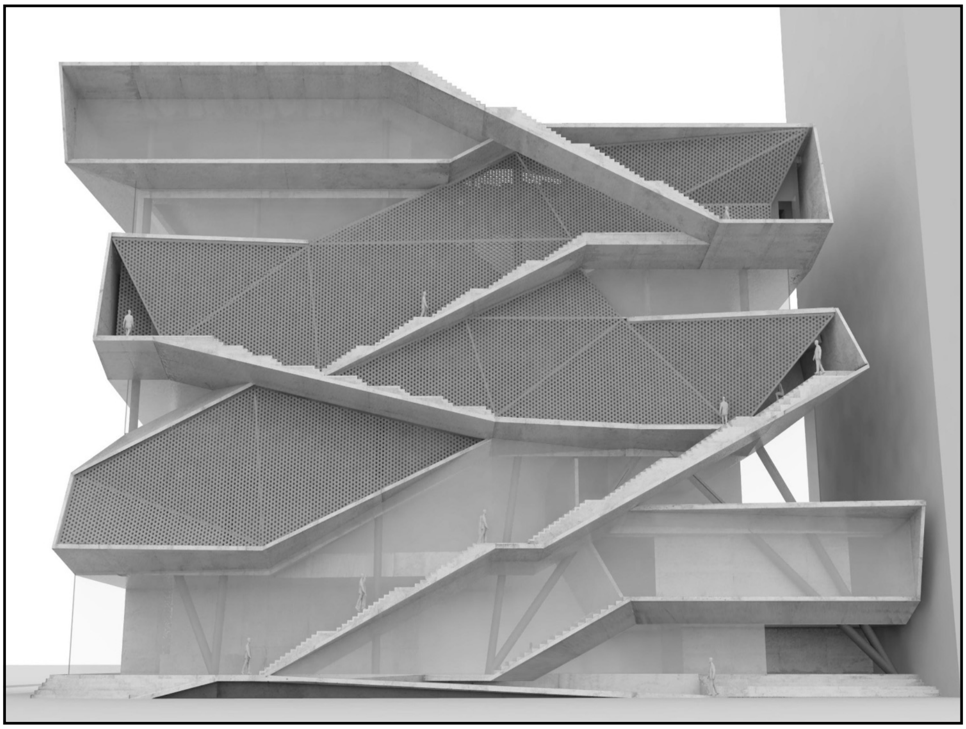

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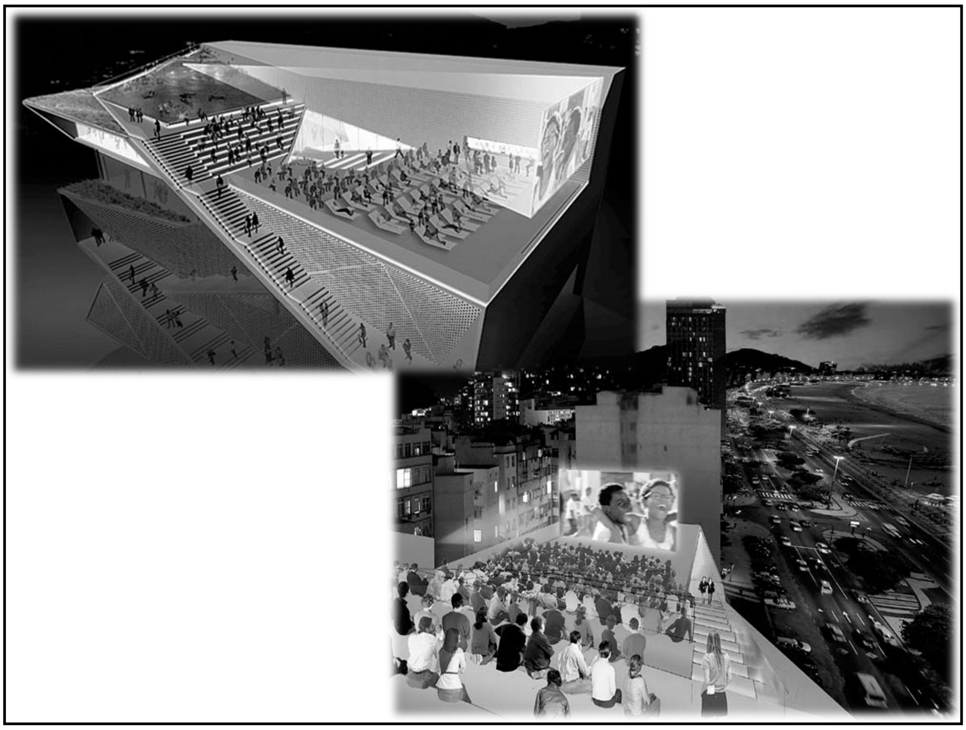

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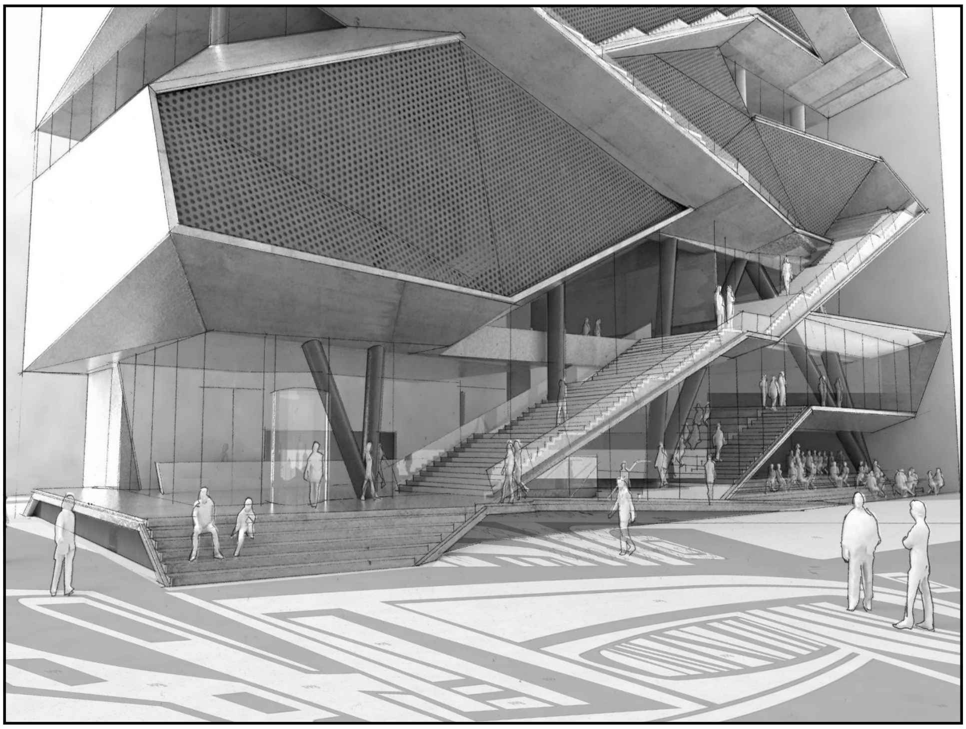
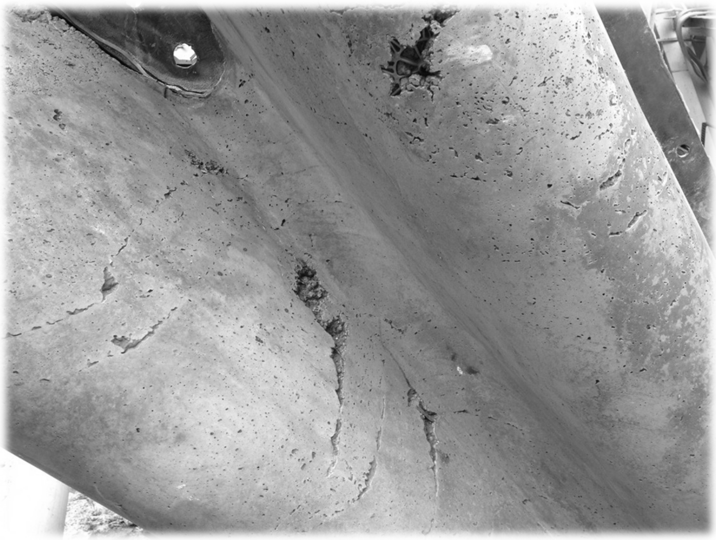


185

Prototype column: conventional concrete, usual procedures, 50MPa, slump 120mm, vibrated)

186

Prototype column: conventional concrete, usual procedures, 50MPa, slump 120mm, vibrated)



187

Prototype column: conventional concrete, usual procedures, 50MPa, slump 120mm, vibrated)

188

Prototype column: conventional concrete, usual procedures, 50MPa, slump 120mm, vibrated)

189

Prototype column: SCC, 50MPa, not vibrated

190

Prototype column: SCC, 50MPa, not vibrated

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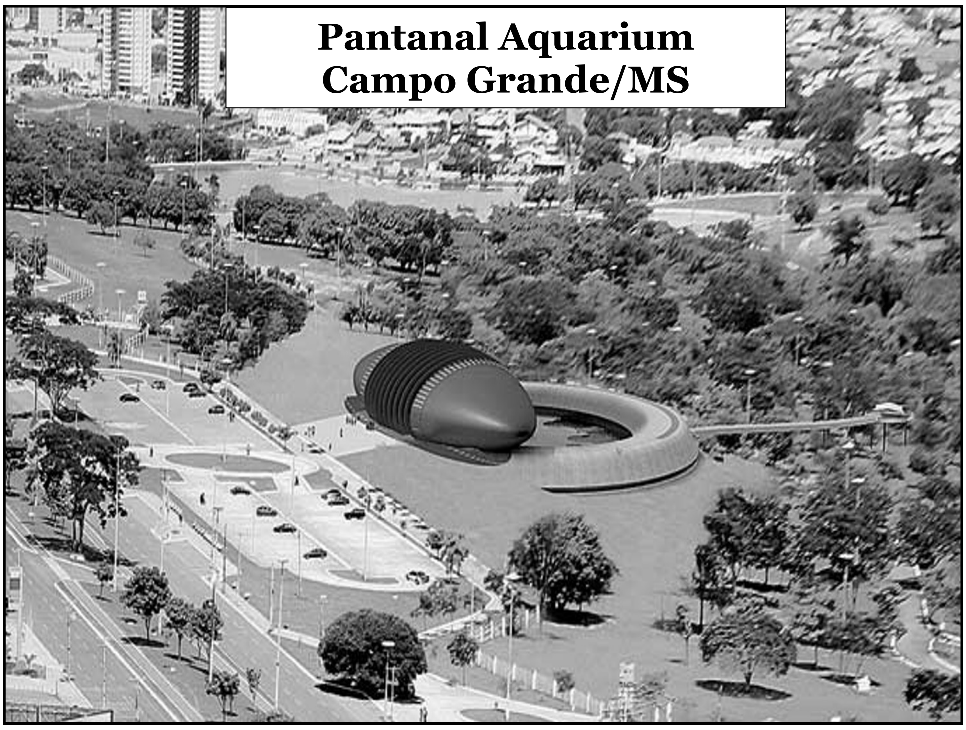
Pantanal Aquarium
Campo Grande/MS



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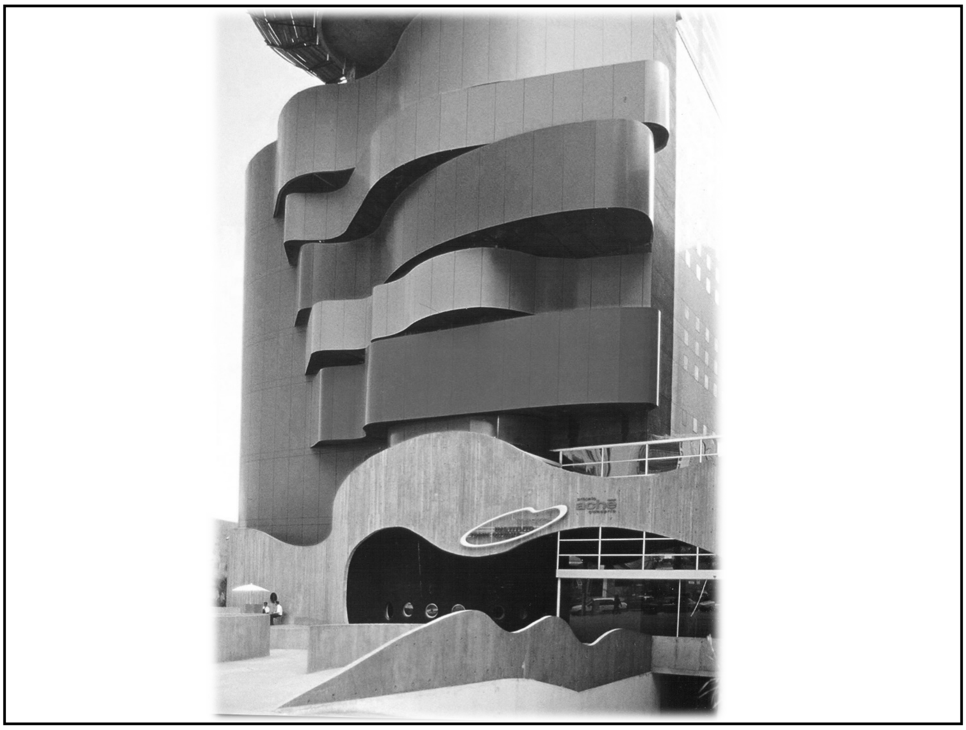
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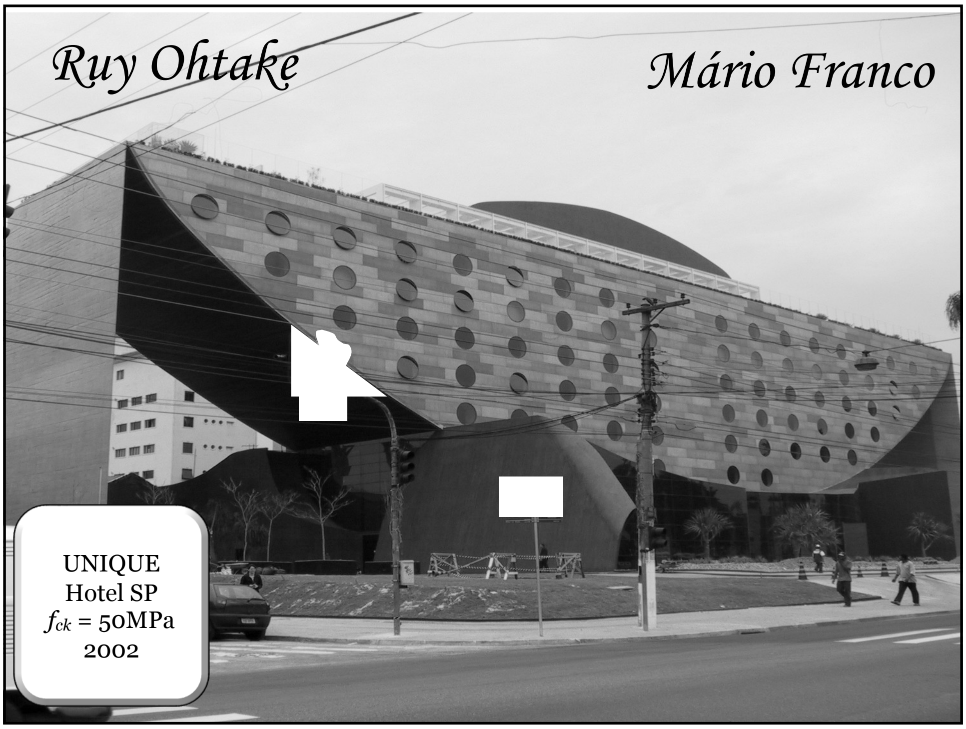

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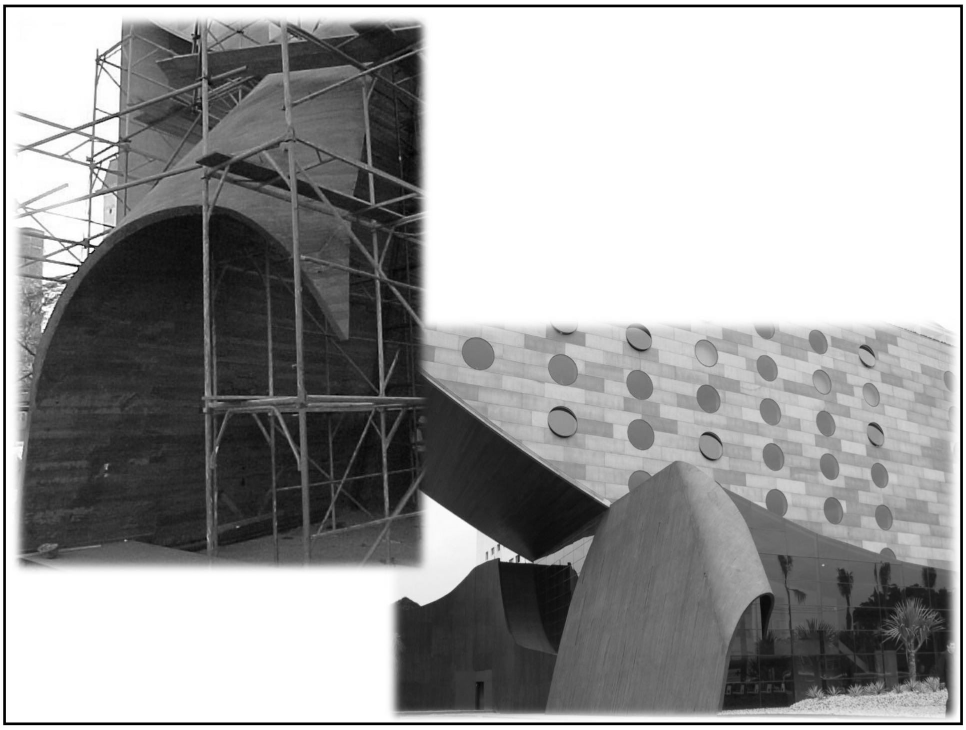

202

Considered by the French press of one of the 7 Wonders of 2003

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Some thoughts

204

Is it correct to carry out growth assessment only by economic indexes?

- ✓ Did the quality of life improve?
- ✓ Did the sanitation and health improve?
- ✓ Were there fewer serious acidentes in construction works?
- ✓ Were there evolution in the technology?
- ✓ Were there evolution in the quality and sustainability of construction works?
- ✓ Were there evolution in the knowledge and technology transfer between Universities, Architecture and Engineer and the companies?
- ✓ Which excellence indexes should be chased?

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Petronas Towers
Cesar Pelli

Kuala Lumpur

Malasia 1997

452m

f_{ck} = 800 kgf/cm²

before / after

206

Today there are more than 100 constructed buildings 300m+ high

CTBUH, 2016

207

From this amount of skycrapers:

- 36 are in concrete
- 54 are composite concrete / steel
- only 10 are in steel

CTBUH, 2016

208

Including the tallest building of the world, Burj Khalifa, in Dubai, with 820m-hig, was constructed in concrete

209

Burj Khalife / Dubai - World tallest (2008)

210

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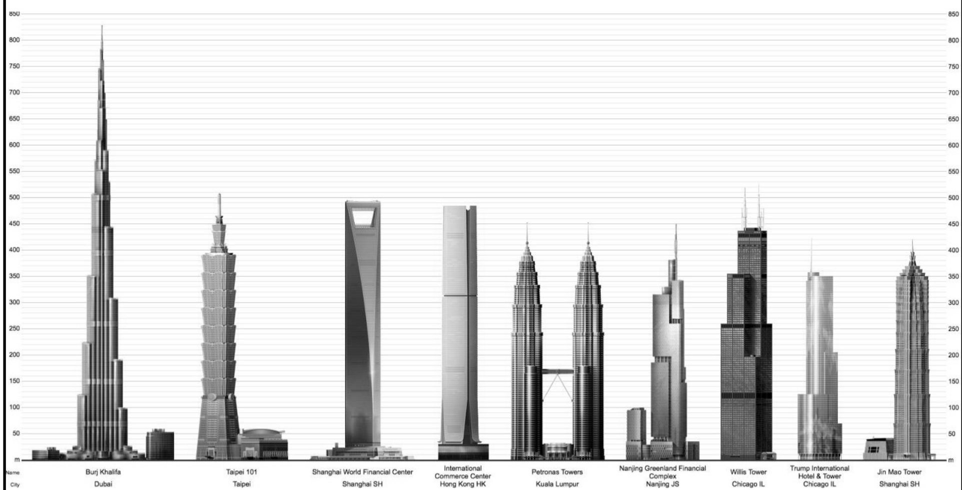
Comparative



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The world tallest building in the future

KINGDOM TOWER

1km-high

Jeddah, Saudi Arabia

The calculations predict that the Kingdom Tower will consume a minimum of 500,000m³ of concrete

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High Performance Structures

→ Reduce the problems risk

→ Demand previous studies

→ Demand the quality management

→ Demand the knowledge and use of standards and existing documents

→ Are a team, nation work…

216

Sustainability combines in gender, number and degree with

Rationalization

Precast Concrete

Industrialization

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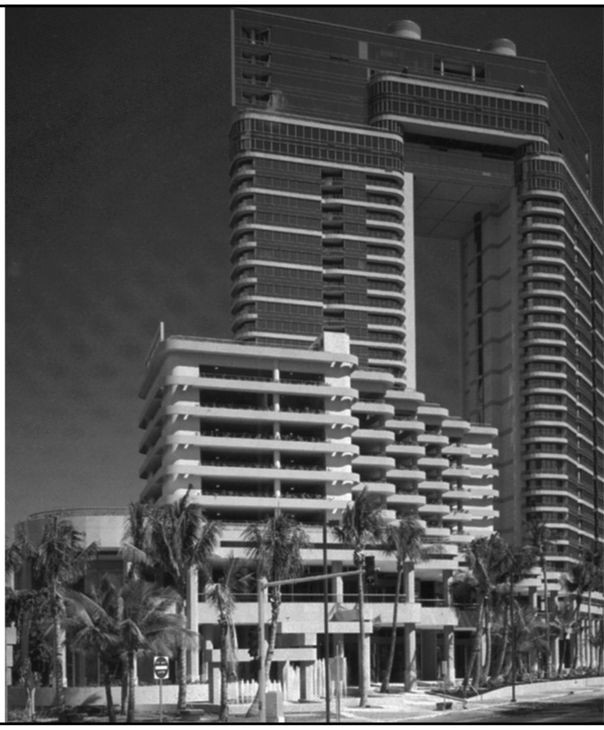

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Top 10 countries for LEED in 2015

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Rank	Nation	GSM of LEED-certified space (million)	Total GSM of LEED-certified and registered space (millions)	Total number of LEED-certified and registered projects
1	Canada	26.63	63.31	4,814
2	**China**	**21.97**	**118.34**	**2,022**
3	India	13.24	73.51	1,883
4	**Brazil**	**5.22**	**24.50**	**991**
5	Republic of Korea	4.81	17.47	279
6	Germany	4.01	8.42	431
7	Taiwan	3.84	9.08	149
8	United Arab Emirates	3.13	53.44	910
9	Turkey	2.95	23.74	477
10	Sweden	2.54	4.20	197
*	United States	276.90	727.34	53,908

GSM = Gross square meters

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