# Ecological With No Performance Compromise

Eco-Mechanical Index for Sustainable Concrete Structural Design


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# THE STORY

- CONTEXT
  - Sustainability – Common Understanding
  - Concrete Sustainability – Until Today
  - Novel Concept for Sustainable Construction
- ECO-MECHANICAL INDEX (emi™)
  - General Idea
  - Details of Concept
- emi™ APPLIED
  - Product Selection Criterion for Structural Engineers
  - Structural Column Design
  - A Materials Design Tool
- CONCLUDING REMARKS

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# A COMMON UNDERSTANDING OF SUSTAINABILITY

**Patterns of Behavior, Attitudes, and Values**

SUSTAINABILITY *goes beyond its economical and ecological dimensions, it is about responsibly designing societies with improved human well-being and social equity.*

# A COMMON UNDERSTANDING OF SUSTAINABILITY

**Definition**

*Sustainable takes its meaning from*

**"sustainable agriculture"** *or "the ability to produce food indefinitely, without causing irreversible damage to ecosystem health."*

# APPLIED (CONCRETE) SUSTAINABILITY

Until Now...


*the words "***green***" and "***sustainable***" are often used interchangeably, and sustainable has a more precise meaning that is often obscured, distorted, and diluted by the commercialization and marketing of the green "movement."*

# APPLIED (CONCRETE) SUSTAINABILITY

**Green ➡ CO2 Footprint**

*Current Sustainability practices are driven by the*

**Green "movement,"** *and emphasis has been*

*on*

**$CO_2$ footprint.**

# APPLIED (CONCRETE) SUSTAINABILITY

**Until Now Green ➡ CO2 Footprint**

*Are these sufficient criterion for designing sustainable structures?*

# CONCRETE SUSTAINABILITY – ADDITIONAL CONSIDERATIONS

**Performance** *cannot be*

*compromised*

*at the*

*expense of* **"Green"**


*Source : Steve Howard-Ted talks - 2013*

# NOVEL CONCEPT IN SUSTAINABLE DESIGN & CONSTRUCTION

## Motivation driving the development of The "eco-mechanical index" (emi™)

*Adopting a parameter such as the emi™, structural engineers can design sustainable structures fulfilling performance requirements (as well as ecological) essential for sound engineering practices*

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# THE ECO-MECHANICAL INDEX

## General Concept

$$EMI = \frac{f(MI)}{g(EI)}$$

EMI = eco-mechanical index

MI = mechanical index

EI = ecological index

f( ) = function used to conbine the MI in the calculation of the EMI

g( ) = function used to conbine the EI in the calculation of the EMI


1. *Eco-Mechanical index for structural concrete – EMI – Fib*
2. *Eco-Mechanical index for structural concrete – Combuildmat*

# THE ECO-MECHANICAL INDEX

**Details: Considerations and Breadth**

**Mechanical characteristics considered for each parameter**

$$MI = f_c \cdot f_{c,fl} \cdot A_F^C \cdot A_F^T \quad [N^2/mm^2]$$

- $f_c$ — Compressive Behavior (CB)
- $f_{c,fl}$ — Tensile Behavior(TB)
- $A_F^C$, $A_F^T$ — Ductility (DU)

**Ecological characteristics considerd for each parameter**

$$EI = \frac{kgCO_2}{m^3_{concrete}} \cdot \frac{GJ}{m^3_{concrete}} \cdot \frac{m^3_{water}}{m^3_{concrete}}$$

- $\frac{kgCO_2}{m^3_{concrete}}$ — CO2 footprint ($CO_2$)
- $\frac{GJ}{m^3_{concrete}}$ — Energy consumption (EN)
- $\frac{m^3_{water}}{m^3_{concrete}}$ — Water consumption ($H_2O$)

# THE ECO-MECHANICAL INDEX

**Details: Considerations and Breadth**

$$MI = \prod_{i=1}^{n} MP_i \cdot \prod_{j=1}^{m} MDCP_j$$

$$EI = \prod_{k=1}^{p} EP_k \cdot \prod_{l=1}^{r} EDCP_l$$

where, $MP_i = i^{th}$ mechanical parameter; $EP_k = k^{th}$ ecological parameter; $MDCPj = j^{th}$ weighting coefficient of mechanical parameter; $EDCP_l = l^{th}$ weighting coefficient of ecological parameter; $n$, $m$, $p$, $r$ = number of $MP$, $MDCP$, $EP$, and $EDCP$, respectively.

# THE ECO-MECHANICAL INDEX

**Details: Considerations and Breadth**

**Final Formulation of the proposed EMI**

$$EMI = \frac{\log_a \left( G_F^C \cdot G_F^T \right)}{\log_a \left( \frac{kgCO}{m^3_{concrete}}^2 \cdot \frac{GJ}{m^3_{concrete}} \cdot \frac{m^3_{water}}{m^3_{concrete}} \right)}$$

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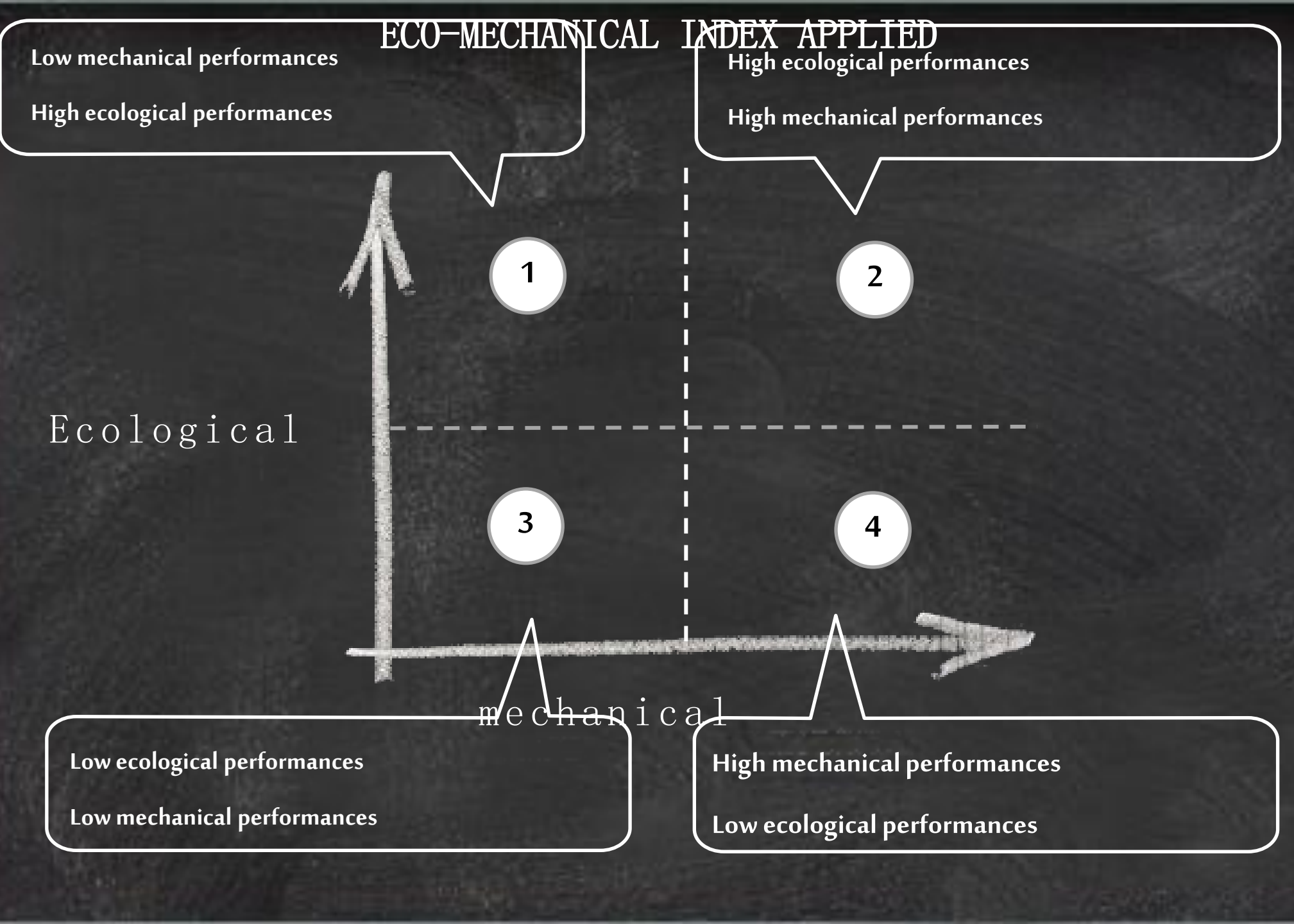
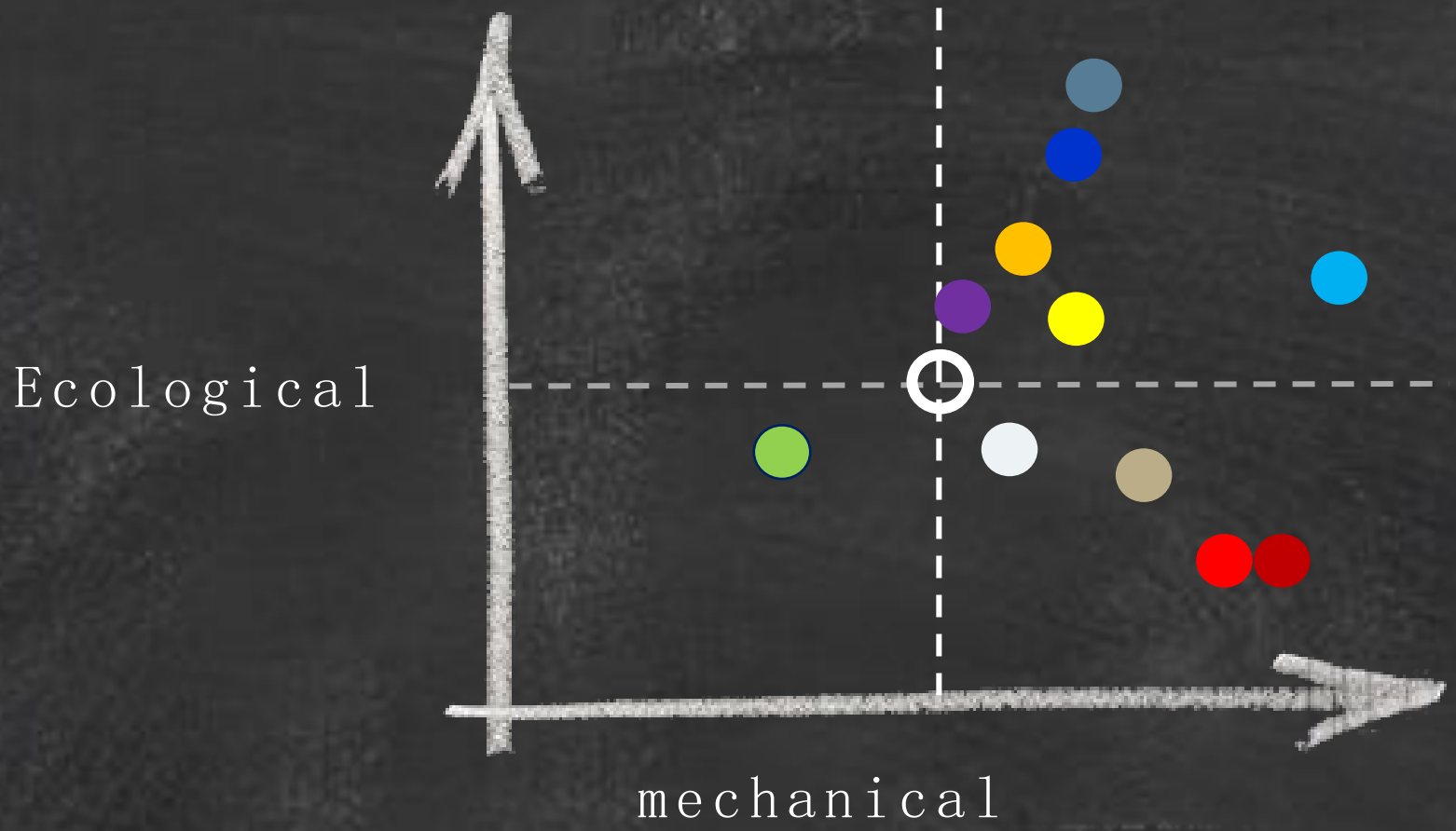
ECO-MECHANICAL INDEX APPLIED

# ECO-MECHANICAL INDEX APPLIED



# ECO-MECHANICAL INDEX APPLIED

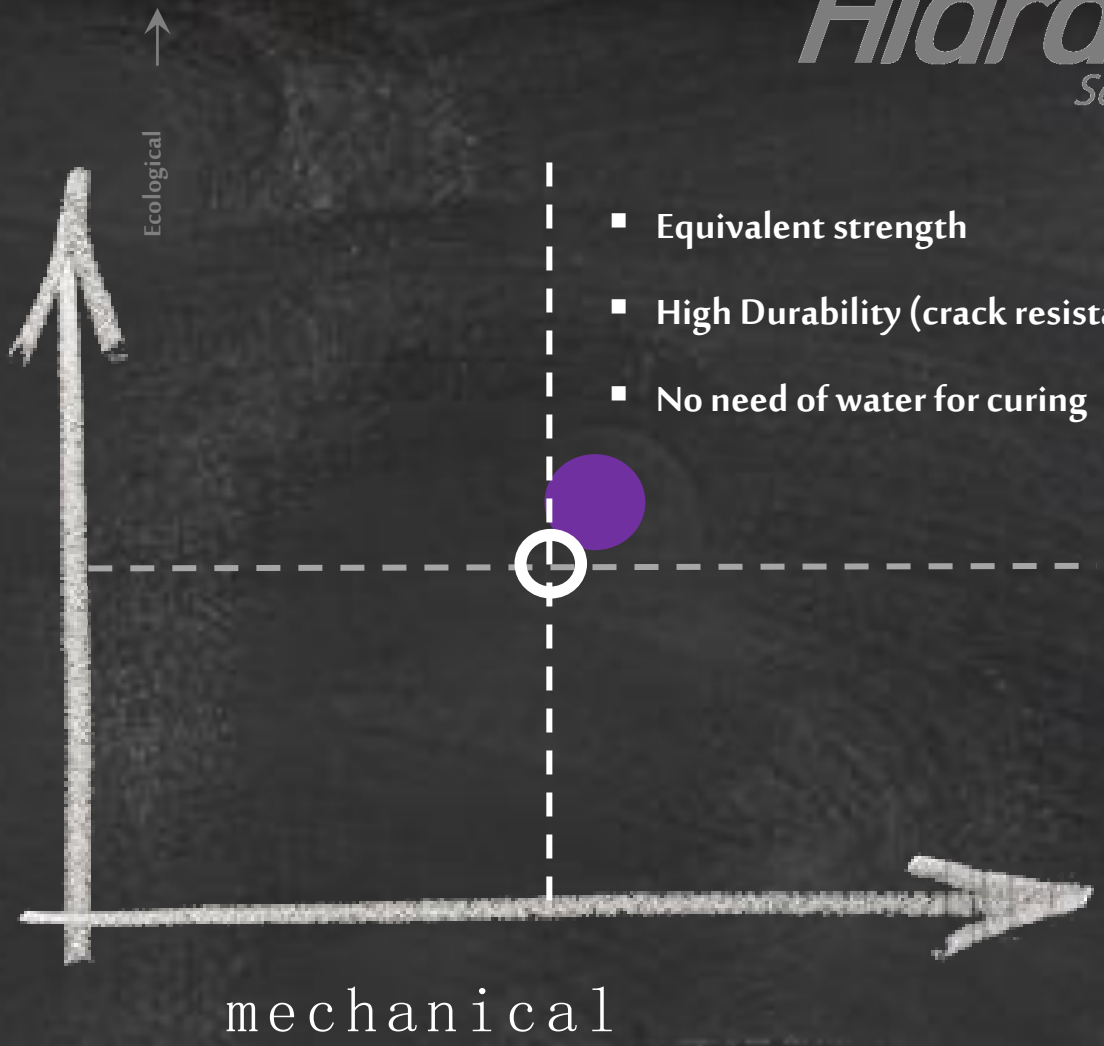
## Biggest RMix Plant in Bogotá




- Conventional concrete
- Insularis B
- Hidratium
- Siuf
- Resilia
- FRC for slab
- Insularis A
- Eco Scc+ Hidratium
- Eco Scc
- Grouting
- Fast Track
- Promptis

# ECO-MECHANICAL - Example 1

Hidratium
Self curing by design




- Equivalent strength
- High Durability (crack resistant)
- No need of water for curing

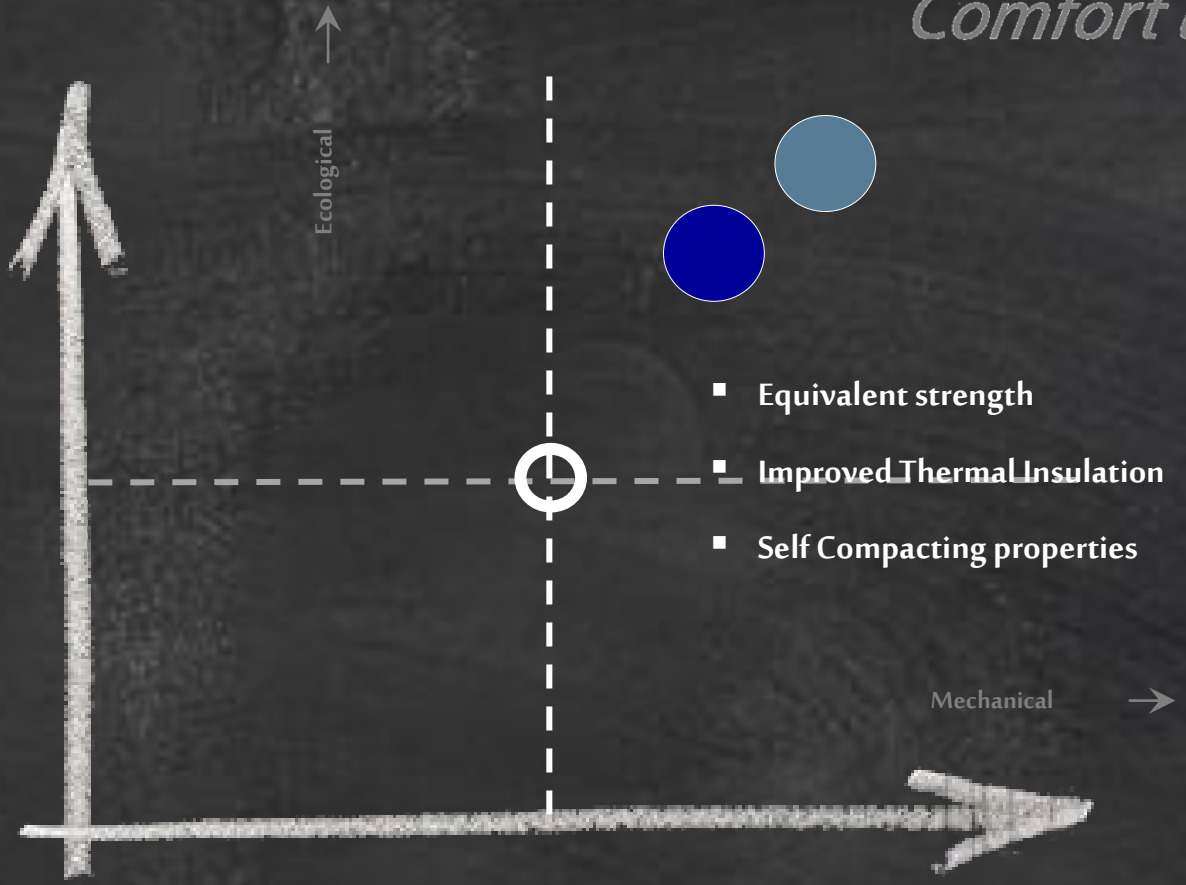
Ecological

Conventional concrete

Hidratium

# ECO-MECHANICAL – Example 2

Insularis
Comfort by design




- Equivalent strength
- Improved Thermal Insulation
- Self Compacting properties

Ecological

mechanical

Conventional concrete

Insularis A

Insularis B

# ECO-MECHANICAL – Example 3

Resilia
Reinforced by design


- Increased strength performances
- Replacement of all reinforcement
- Self Compacting properties

Ecological

mechanical

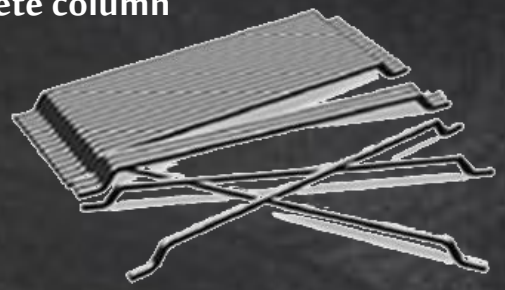
Conventional concrete

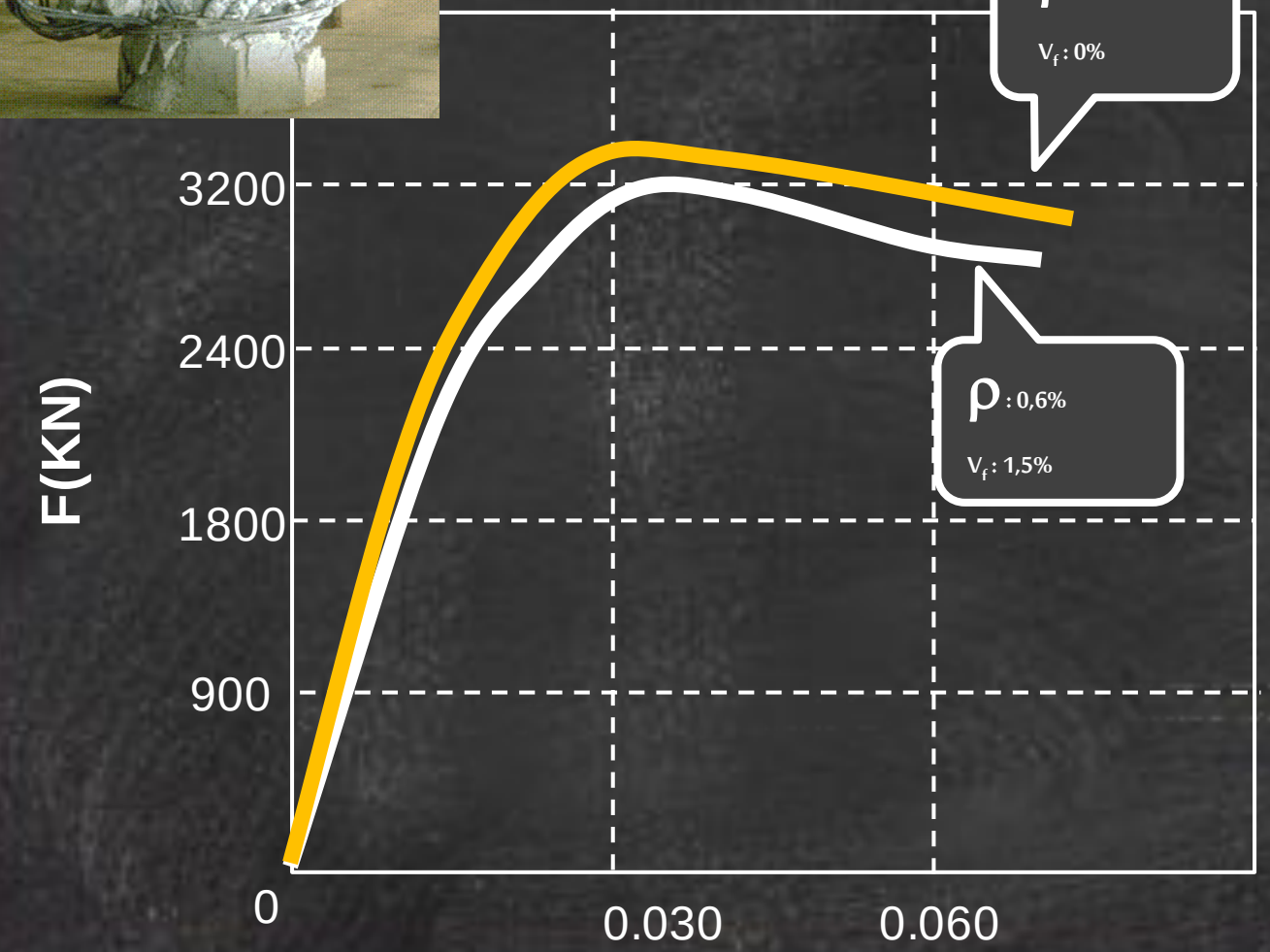
FRC for Slab

Resilia

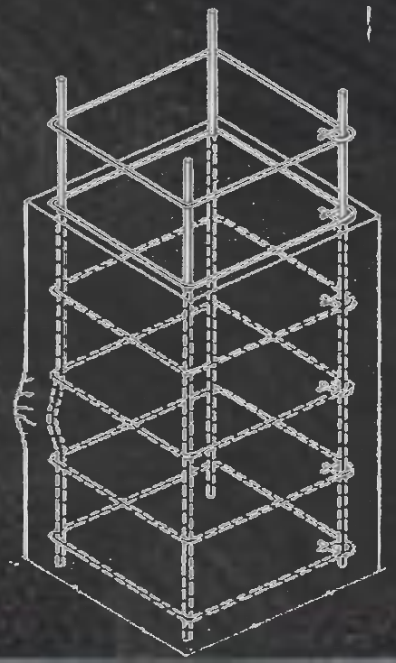
# ECO-MECHANICAL Column Design

SCC fiber reinforced concrete column



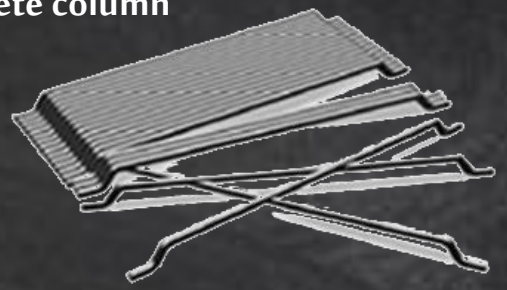



Standard Reinforc
column

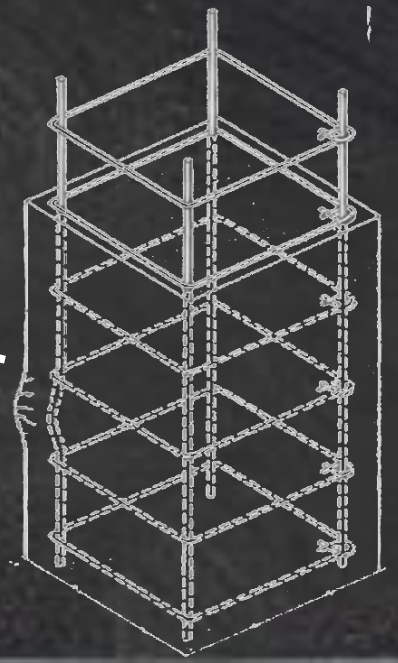


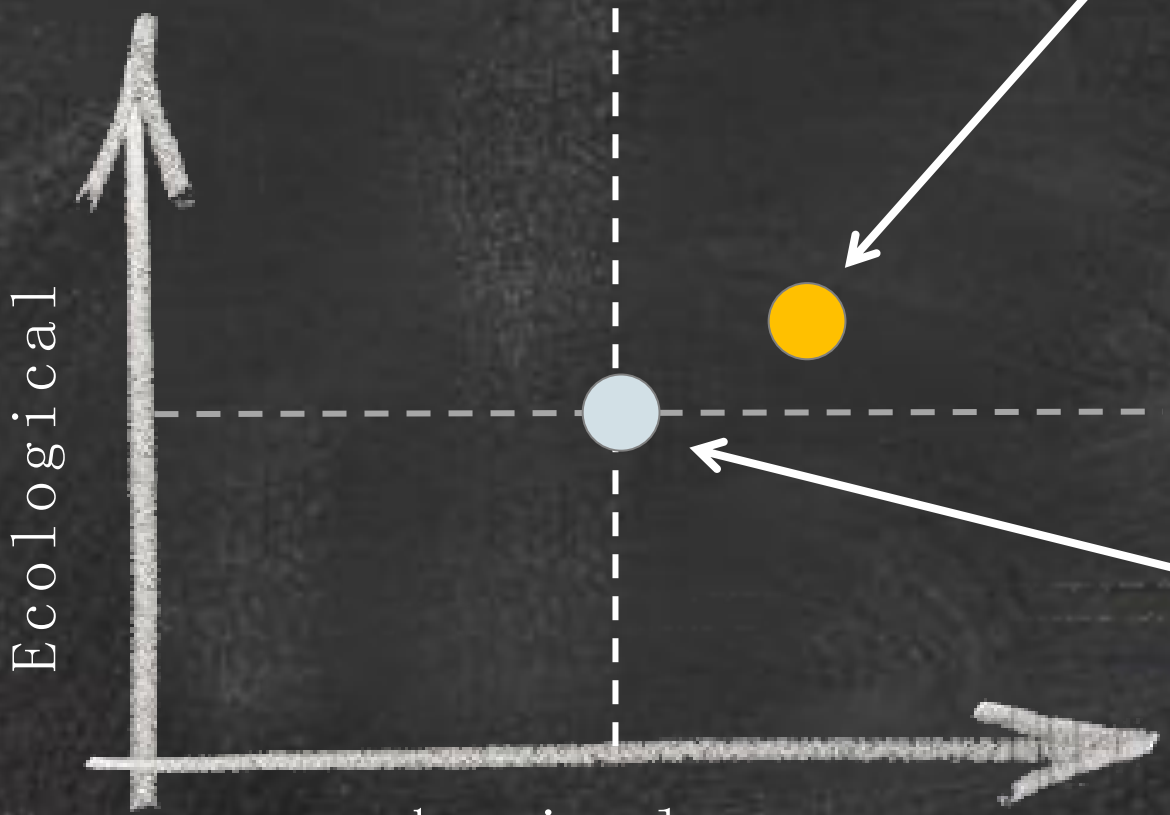
# ECO-MECHANICAL - SUPPORT For ENGINEERS

SCC fiber reinforced concrete column



Standard Reinforc
column





# ECO-MECHANICAL INDEX – concrete design

**Name of the mix *** Water Proof

**Mix design [kg/m3]**

| BINDERS | | FIBERS | |
|---|---|---|---|
| Cement * | 350 | Steel Fibers | 30 |
| Fly ash | | Polypropilen Fibers | |
| Silica fume | | Glass Fibers | |
| Carbonate filler | | | |

| AGGREGATES | | ADMIXTURES | |
|---|---|---|---|
| Aggregates * (sand/gravel) | 1700 | Super plasticizer | 1 |
| Recycled aggregates (sand/gravel) | | Air entrainer | |
| | | Stabilizer | |
| | | Retarder | |
| | | Water Proofer | |
| WATER | | | |
| Water * | 150 | Accelerator | 2 |

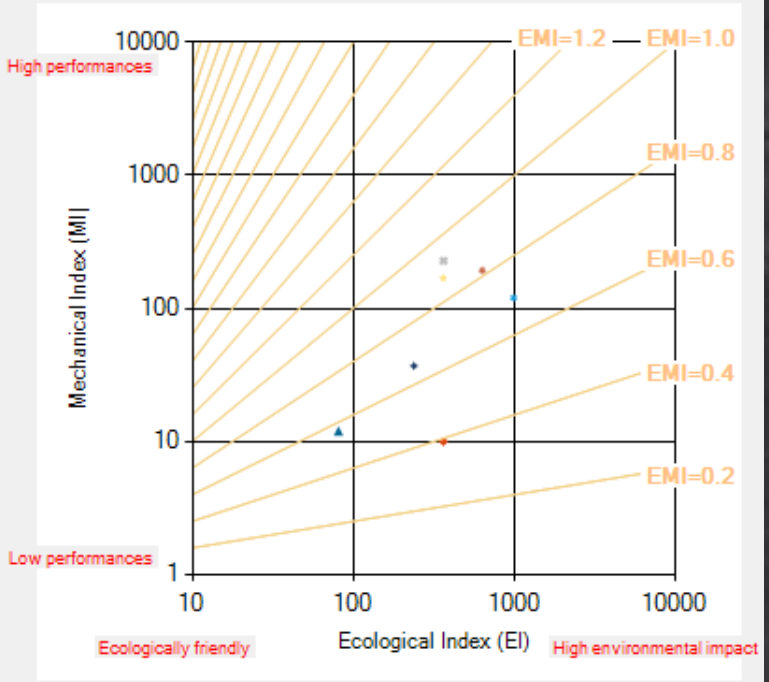
*= to be compulsory filled

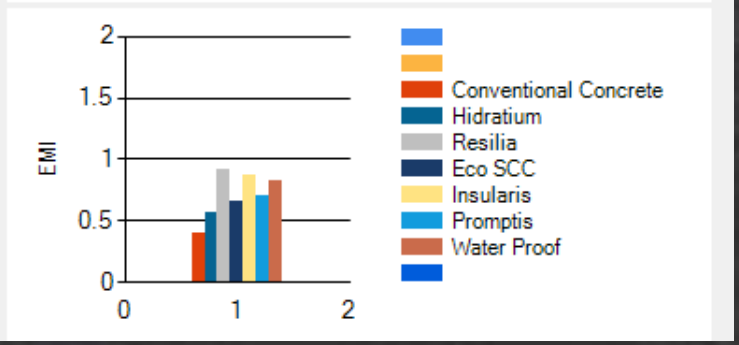
**Eco -mechanical analysis**

| | |
|---|---|
| Ecological Index | 633 |
| Mechanical Index | 193 |
| Eco-Mechanical Index | 0.816 |

CALCULATE

C

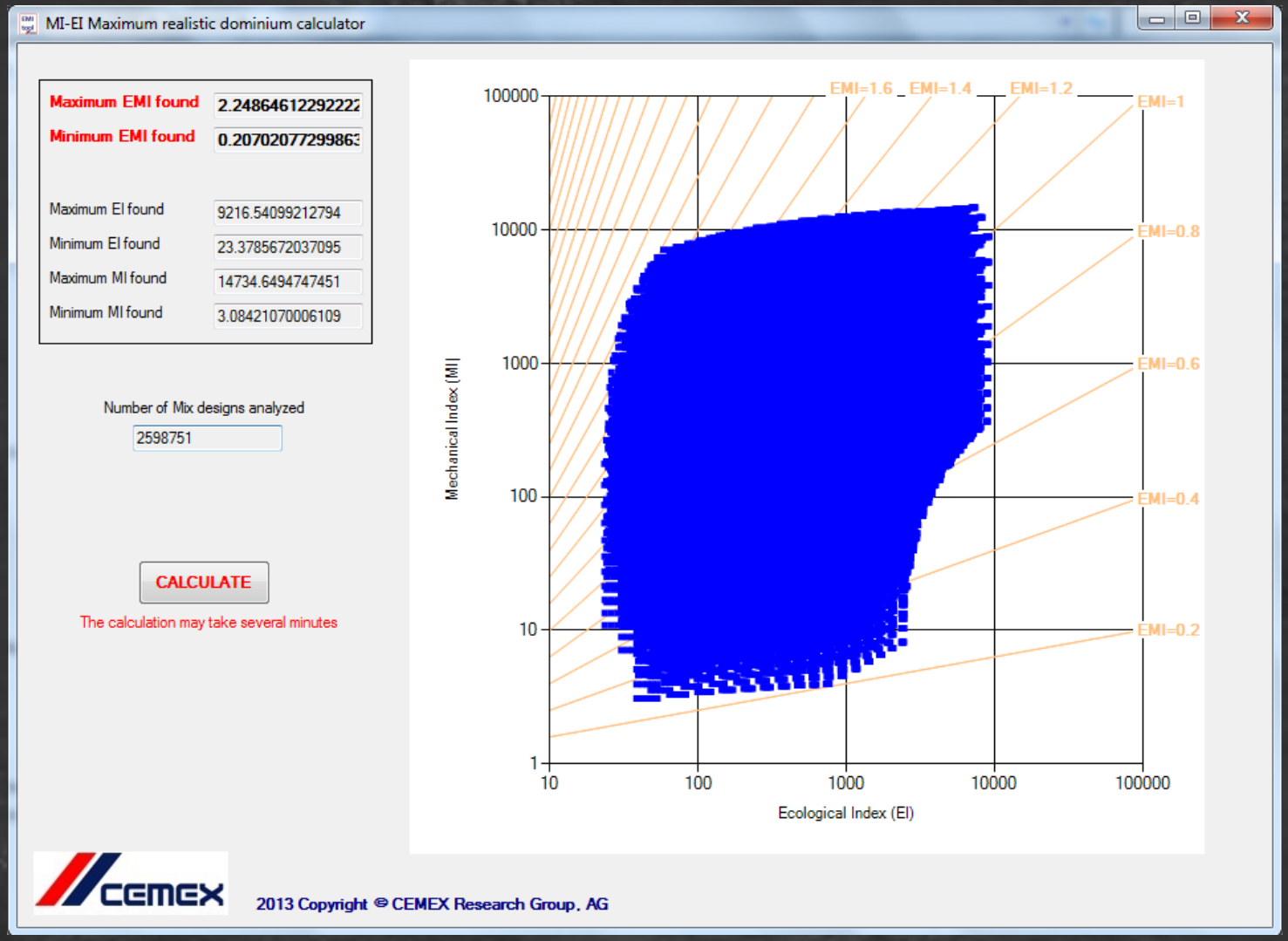





On line tool : Calculation and/or Simulation functionality

# ECO-MECHANICAL INDEX – the sustainability envelope




**Maximum theoretical emi™ based on state of the art simulation**

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# CONCLUDING REMARKS

- **A novel indicator for sustainability is proposed…**

  The Eco-Mechanical Index (emi™) not only accounts for environmental impact, but also considers material performance.

- **The emi™ has been subjected to an initial validation** through its application in an actual sustainable structural design and ready-mix plant products classification.

- **Structural/Design Engineers have a means to communicate their needs and select, compare, and specify** products/solutions with the optimum criterion for sustainability.

- **Powerful means to simulate a variety of product design options**, and select the targeted emi™.

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# THANK YOU

ACKNOWLEDGEMENTS

CEMEX Research Group

Alexandre Guerini

Giovanni Volpatti

Anthony Ponge

Politecnico di Torino

Bernardino Chiaia

Alessandro Fantilli

## APPROACH Factors involved in the EMI formulation

| Parameters | Abbreviation | Importance |
|---|---|---|
| Compressive Behavior | CB | High |
| Tensile Behavior (through Flexure) | TB | High |
| Ductility of the material | DM | High |
| Elastic modulus | EM | Medium |
| Workability | WO | Medium |
| Durability | DU | Medium |
| Density | DE | Low |
| Heat of Hydration | HH | Low |
| $CO_2$ footprint | $CO_2$ | High |
| Energy Consumption | EC | High |
| Waste Reutilization | WR | Medium |
| Water Utilization | $H_20$ | High |
| Energy Efficient Design | EED | Low |
| Healt | HE | Low |
| Thermal Transmission | TT | Low |
| Human Factors and the living/working environment | HF | Low |
| Safety and security | SS | Low |
| Local Economical Impact | LEI | Low |
| Resilience with Climate Changes | RCC | Low |