aci CONCRETE CONVENTION

Sustainability of Concrete Structures: an Italian Perspective

Structural Concrete with Recycled Aggregates: Challenges and Perspectives

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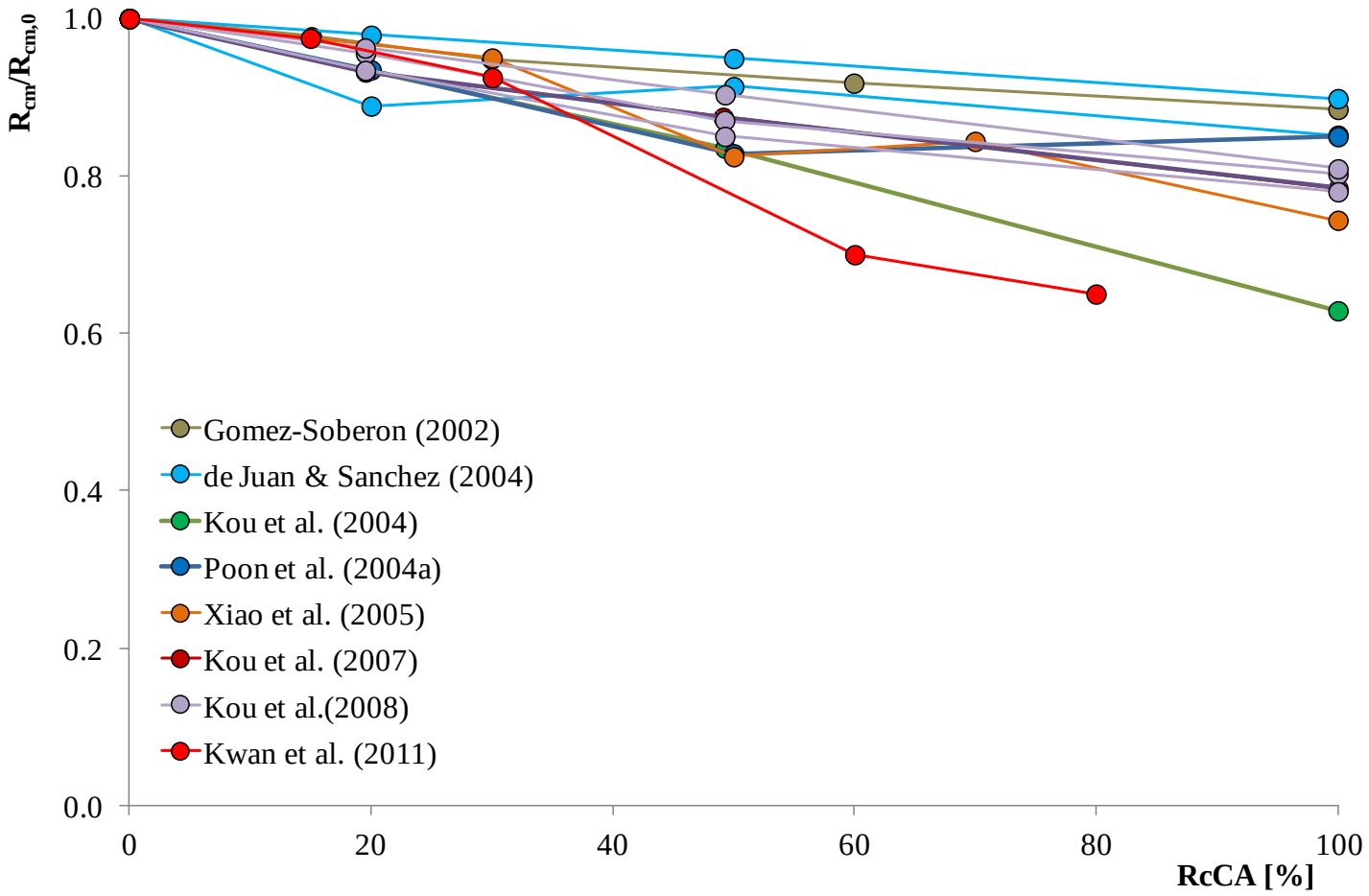
esis s.r.l.
Tecnologie Emergenti a Servizio dell'Ingegneria Strutturale
SpinOff

Introduction

Empirical evidence about the influence of RCAs



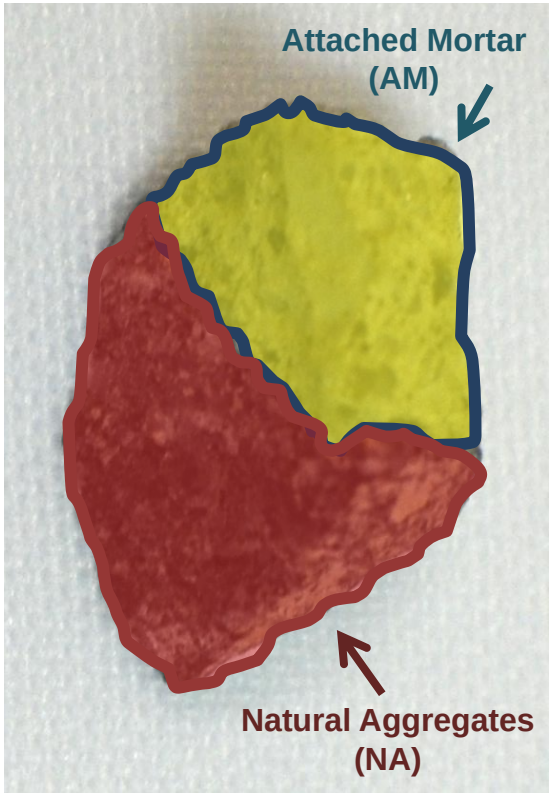
A rational approach to mix design

Natural vs Recycled Concrete Aggregates

Natural Aggregate

Different properties compared with "ordinary" aggregates

NA+AM



Recycled Concrete Aggregate (RAC)

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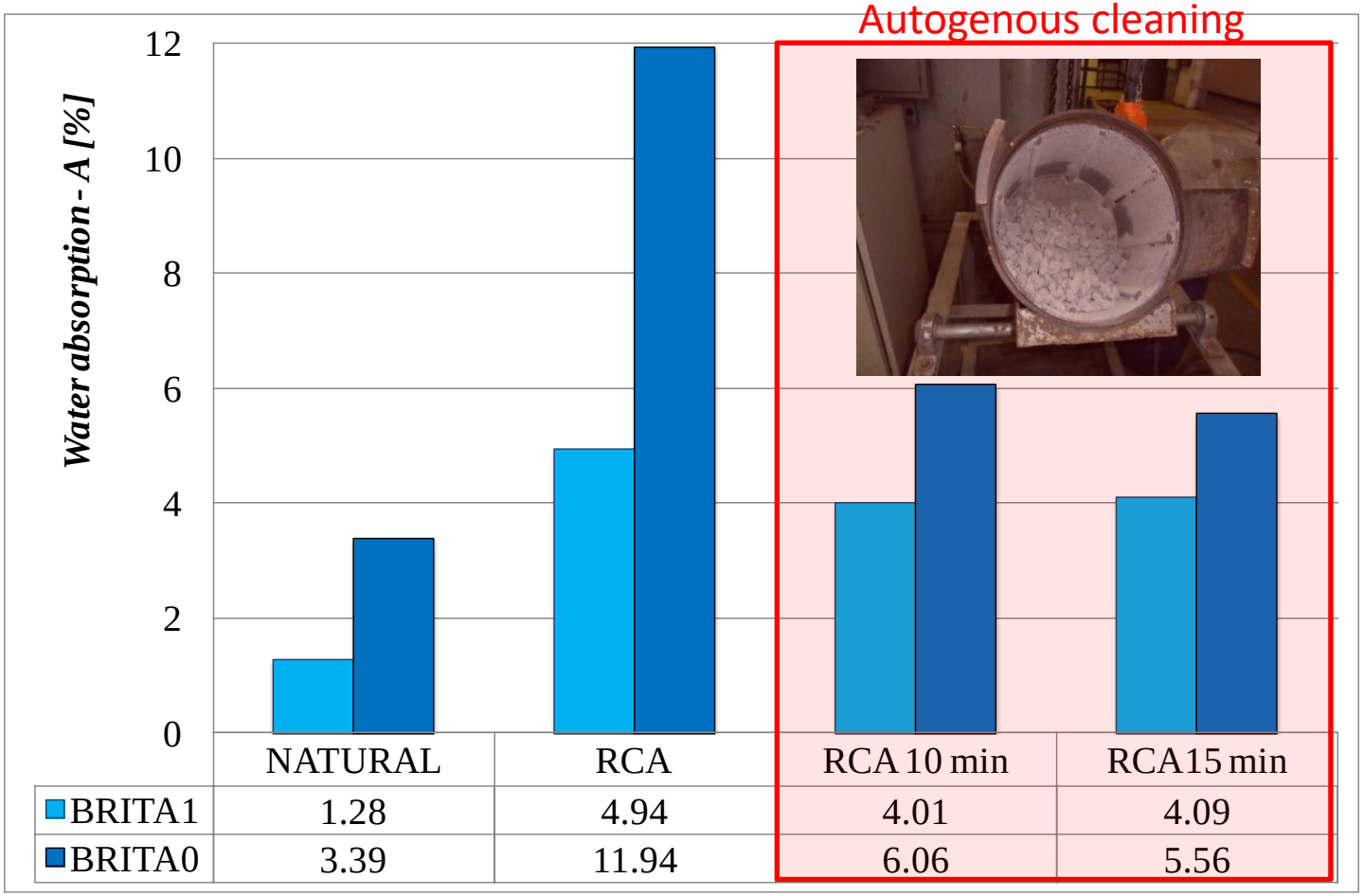
Porosity and water absorption



	NATURAL	RCA	RCA 10 min	RCA15 min
BRITA1	1.28	4.94	4.01	4.09
BRITA0	3.39	11.94	6.06	5.56

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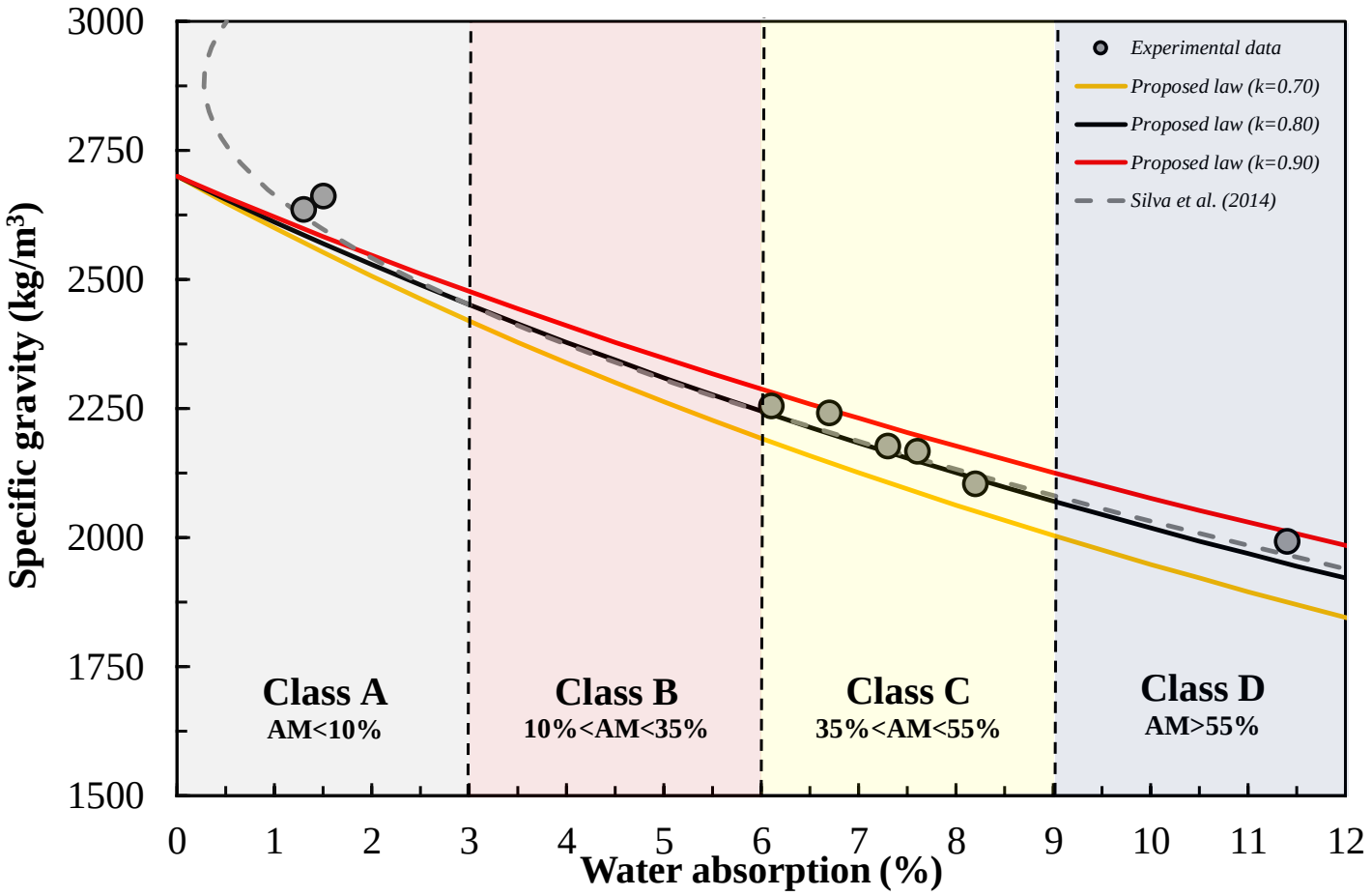
The «quality» of Recycled Concrete Aggregates

$$\gamma_{DRY} = \gamma_m \cdot \frac{1}{1 + \frac{A}{k} \cdot \frac{\gamma_m}{\gamma_{water}}}$$



Coarse aggregates

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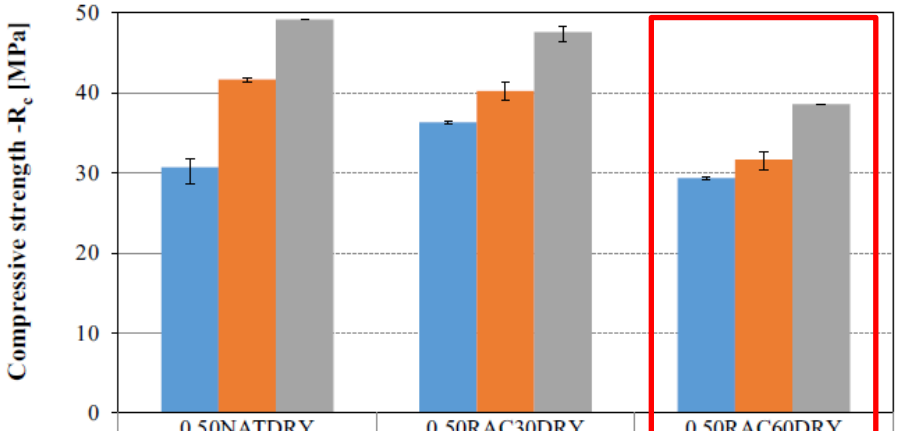
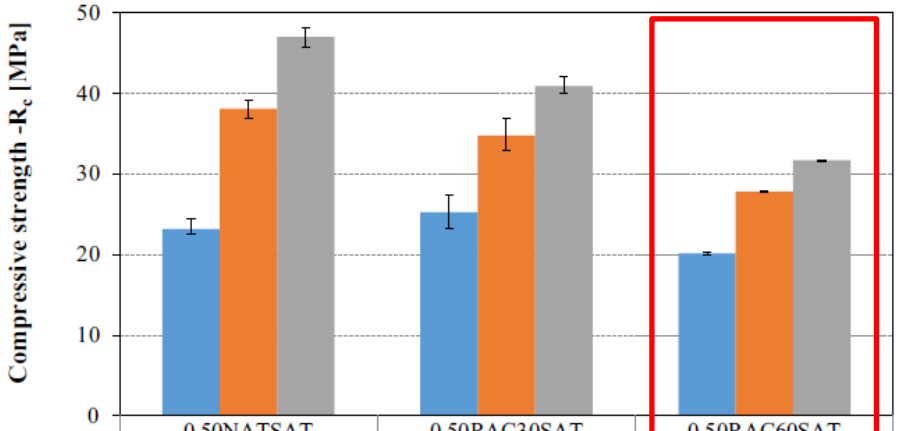
The role of the initial moisture conditions



	0.50NATDRY	0.50RAC30DRY	0.50RAC60DRY
1 day	30.67	36.29	29.35
3 days	41.65	40.20	31.65
28 days	49.12	47.55	38.57

Dry aggregates



	0.50NATSAT	0.50RAC30SAT	0.50RAC60SAT
1 day	23.16	25.24	20.15
3 days	38.06	34.73	27.79
28 days	47.00	40.88	31.66

Saturated aggregates

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Defining an «Effective» w/c ratio

The experimental observations pointed out the following relevant parameters controlling the compressive strength f_c:

- ✓ water/cement ratio;
- ✓ aggregate replacement ratio;
- ✓ aggregate porosity (mass density or absorption capacity);
- ✓ initial moisture condition (DRY/SAT).

Nominal water-to-cement ratio

Weight of the "i" fraction

$$\left(\frac{w}{c}\right)_{eff} = \frac{w}{c} + \frac{w_{add}}{c} - \delta \cdot \left(\sum_{i=1}^{n} \frac{p_i \cdot P_i}{c}\right)$$

Water for saturation

Moisture condition
Rate of absorption

Porosity of class "i" fraction

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Main references

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

A novel mix design methodology for Recycled Aggregate Concrete

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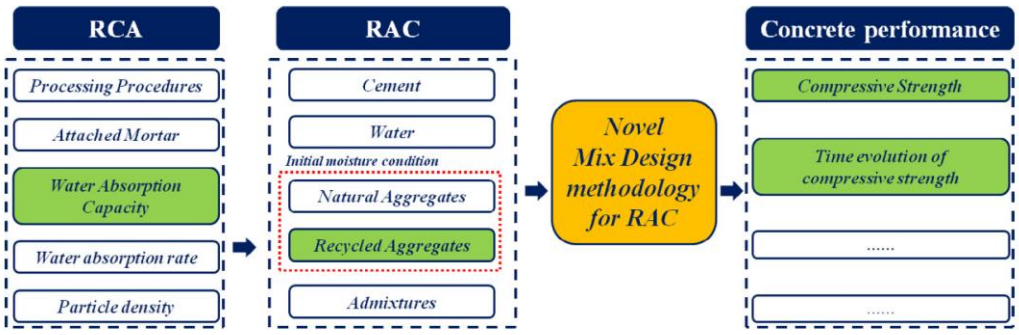
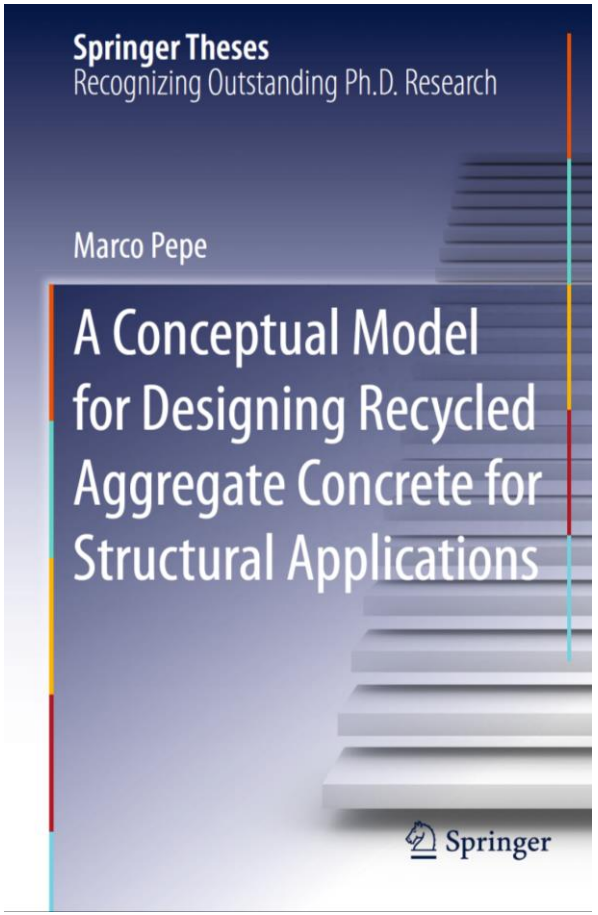
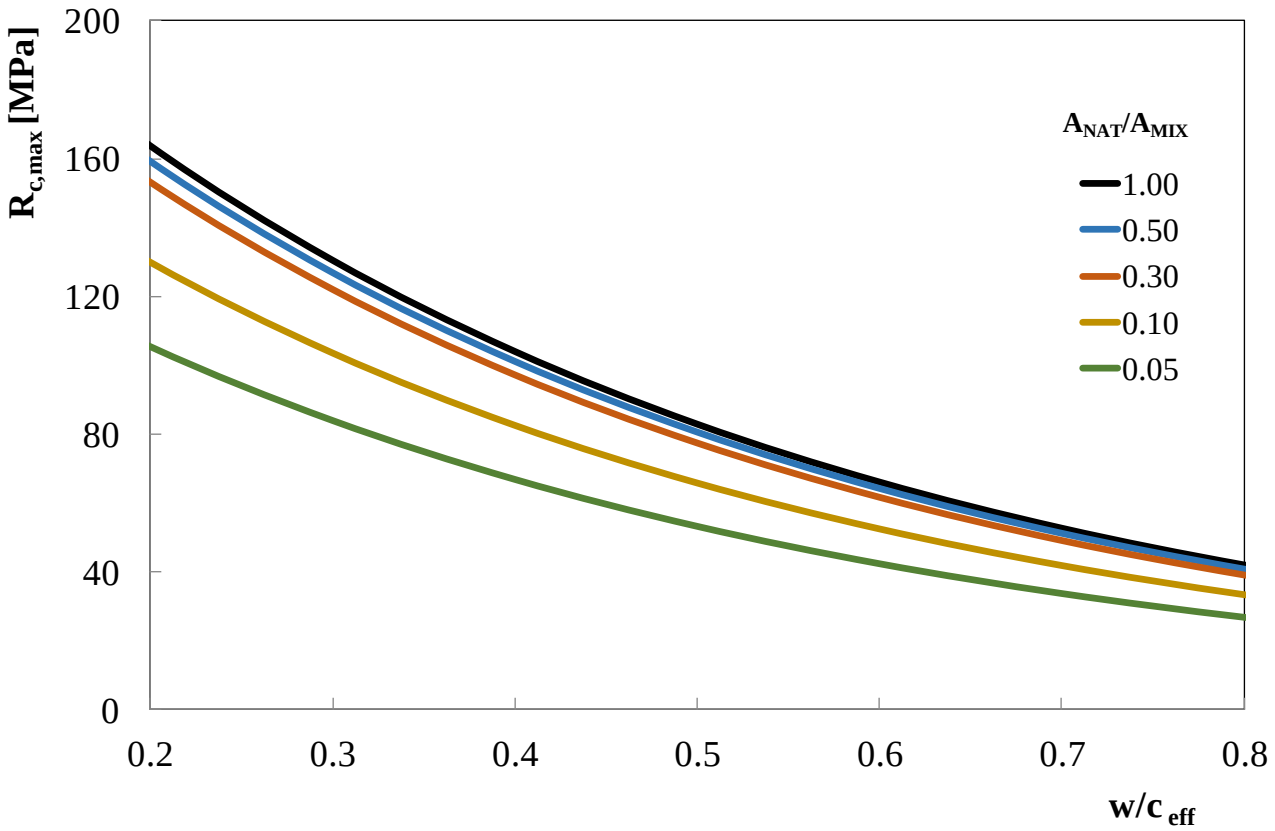




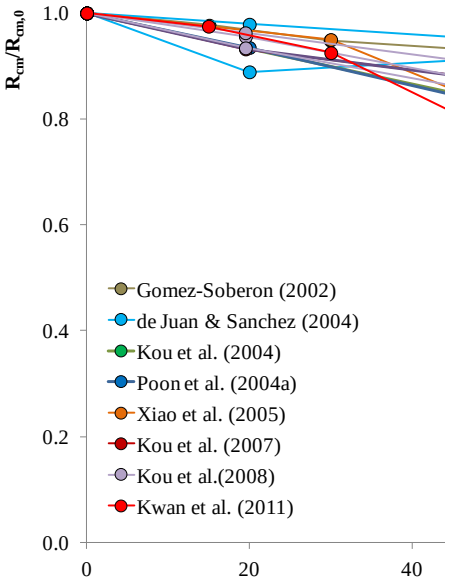
A rational approach to mix design

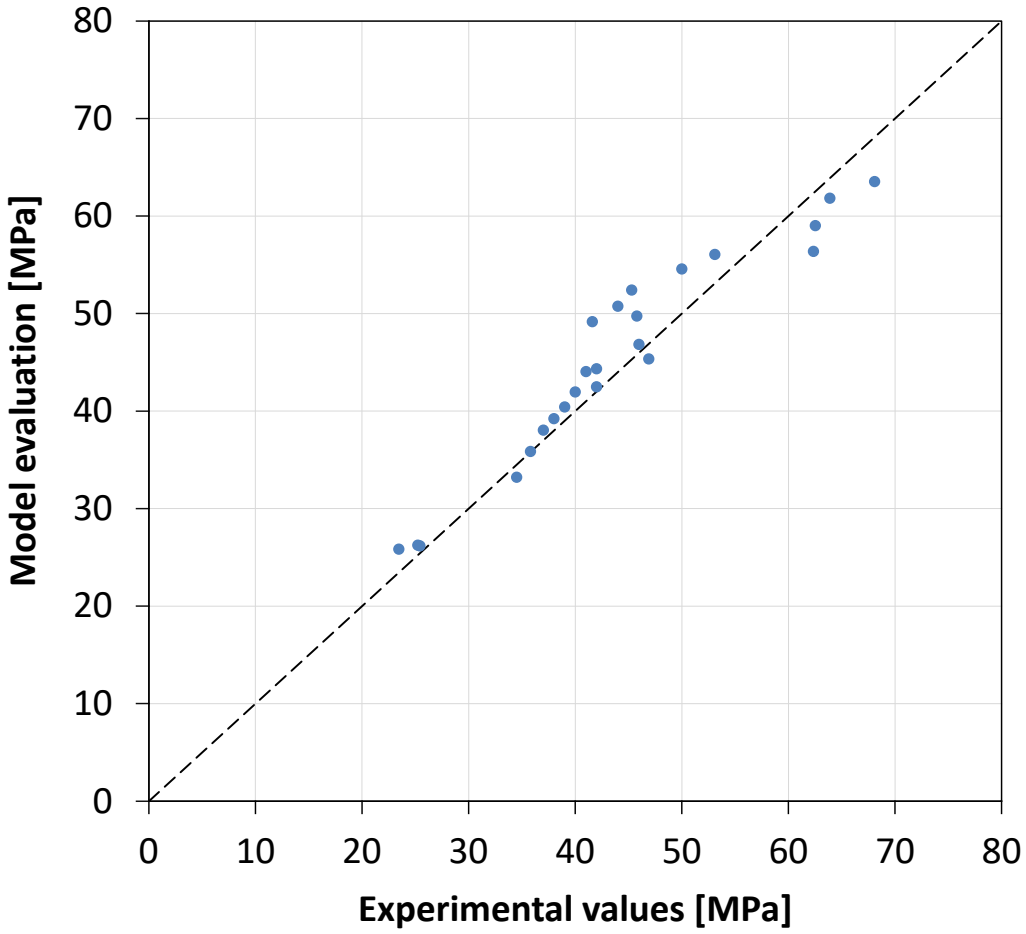
A generalized Abrams' law for RAC



A rational approach to mix design

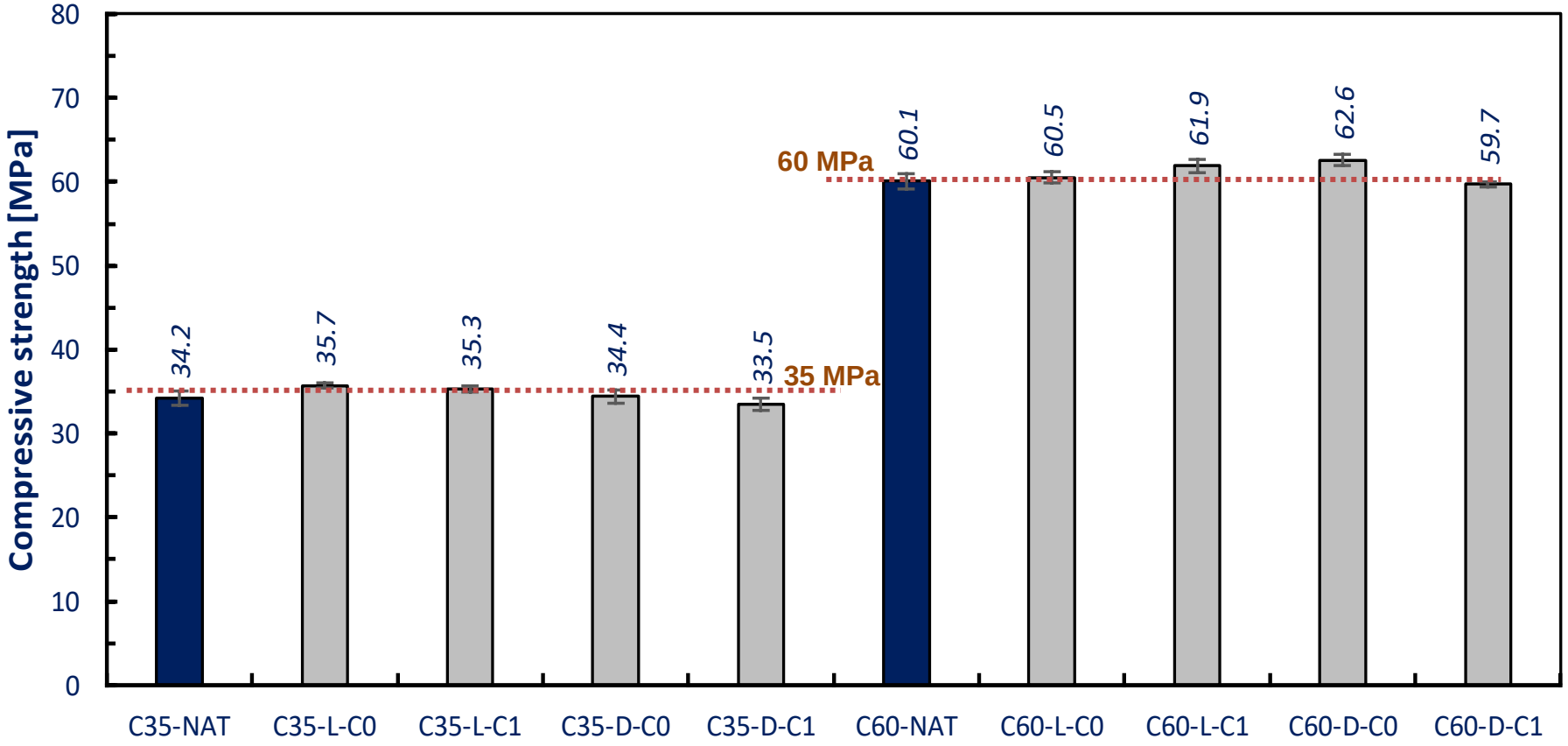
Validation





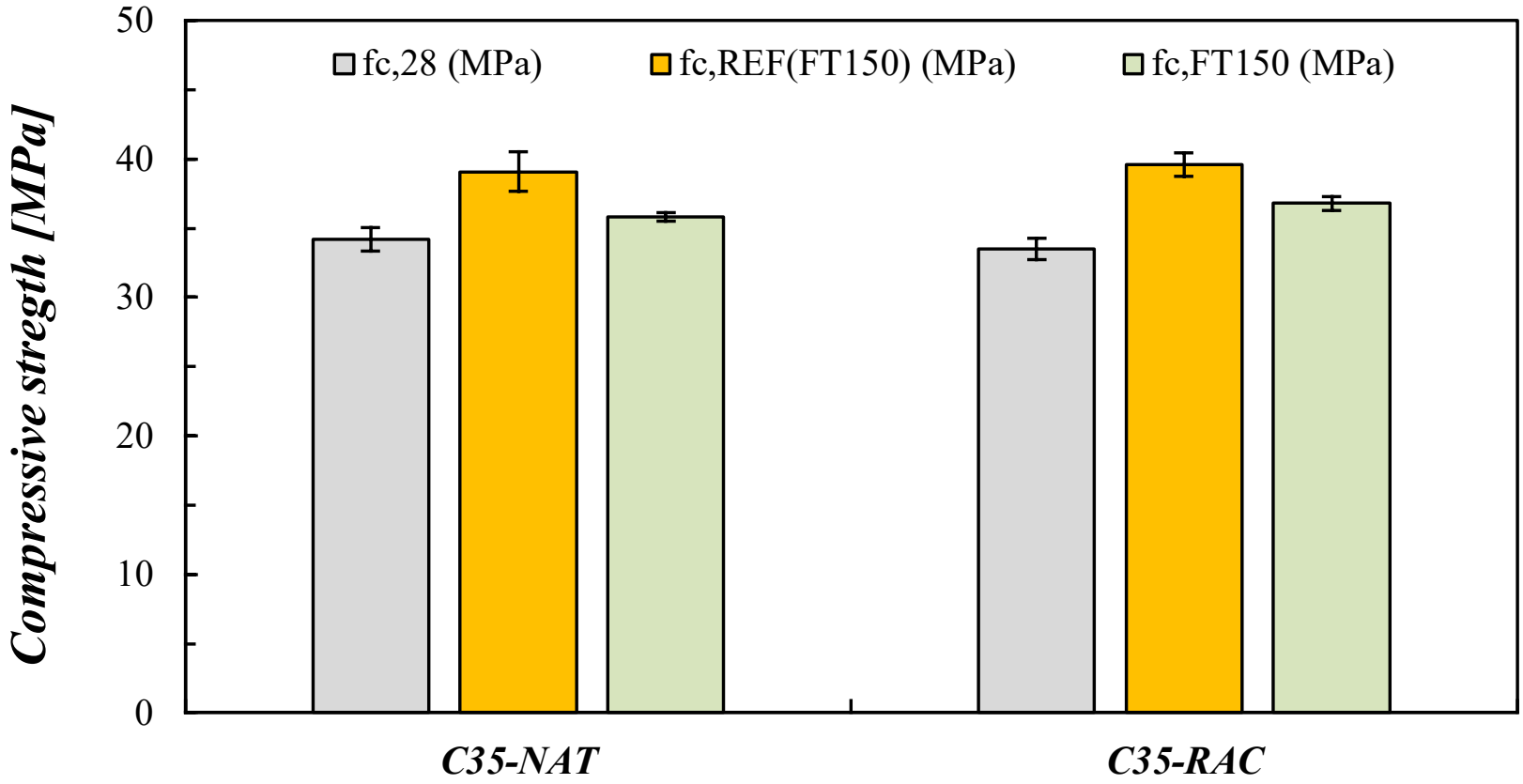
Recyled Aggregate Concrete

Low and medium strength concretes



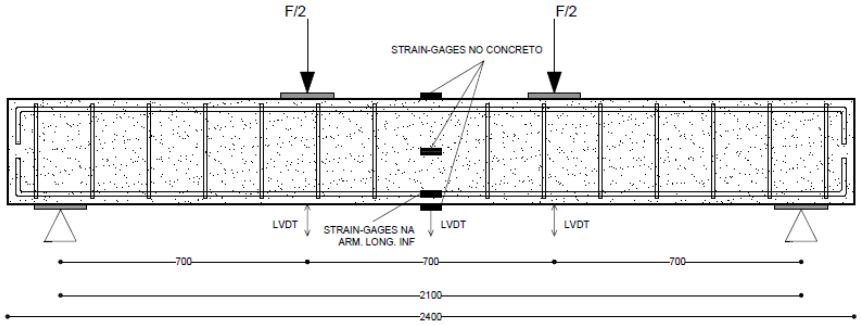
Recyled Aggregate Concrete

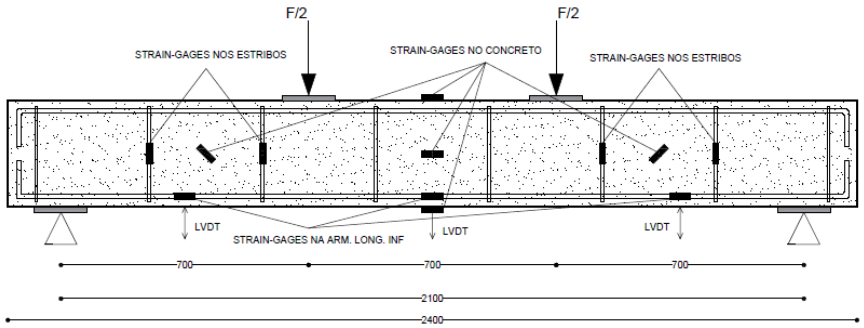
Ordinary Concrete vs. RAC: durability (F/T cycles)



Recyled Aggregate Concrete

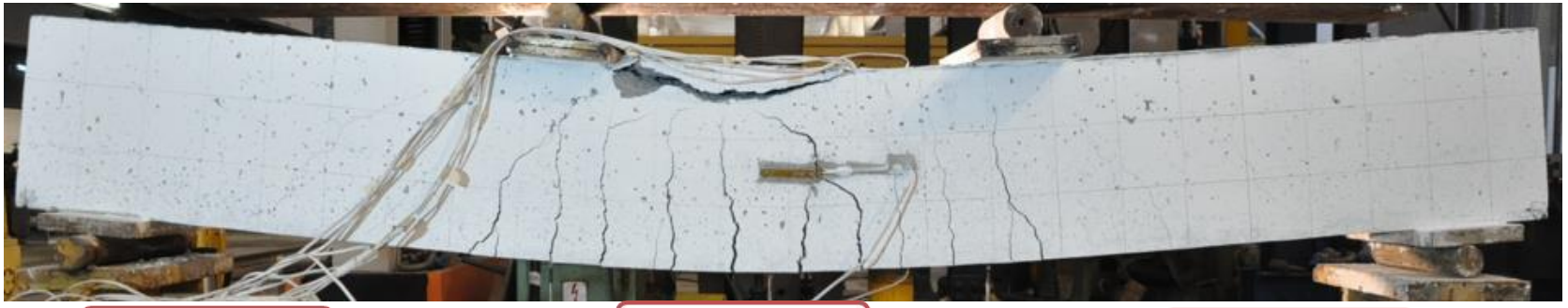
Ordinary Concrete vs. RAC: structural response

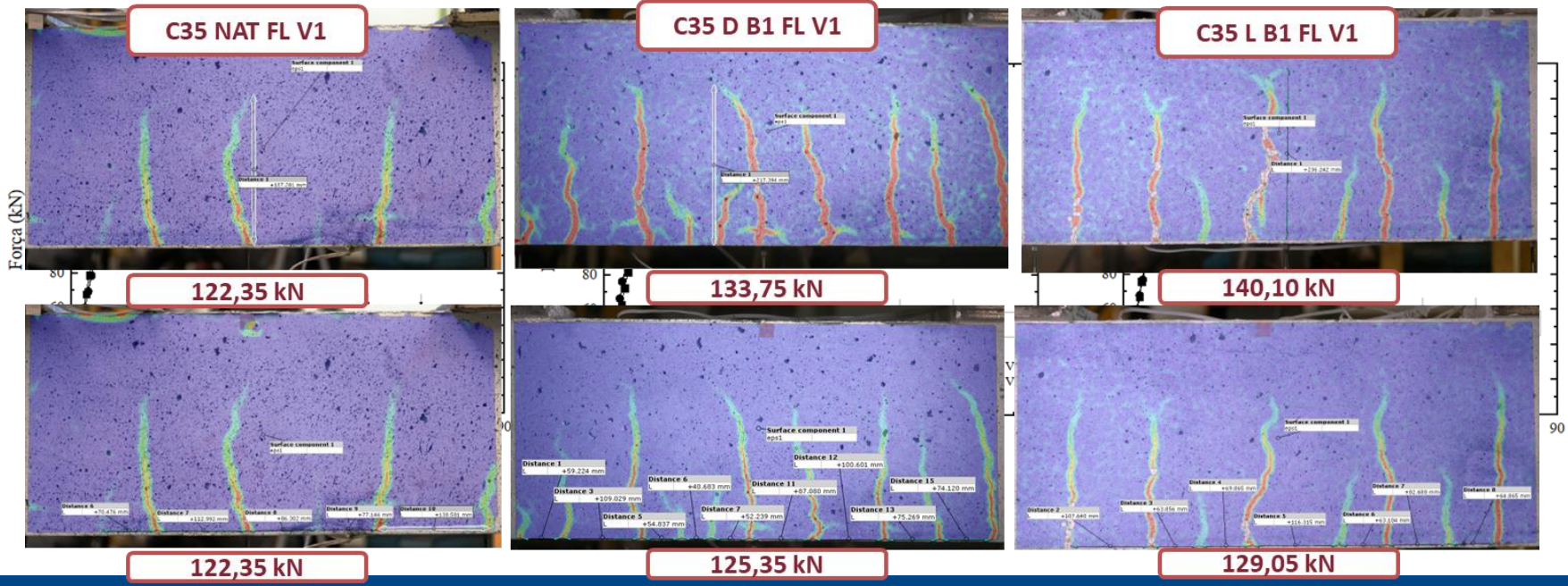




Recyled Aggregate Concrete

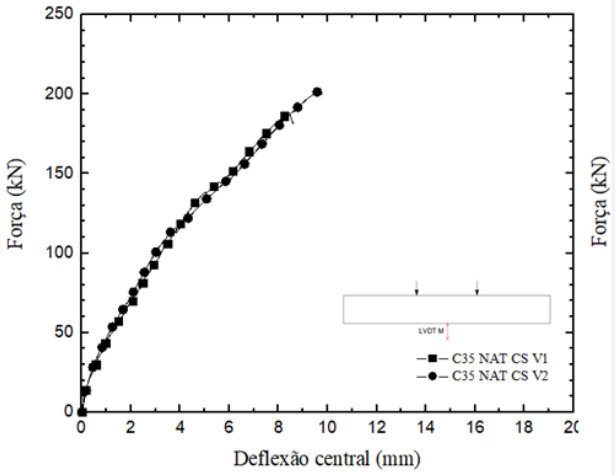
Ordinary Concrete vs. RAC: structural response



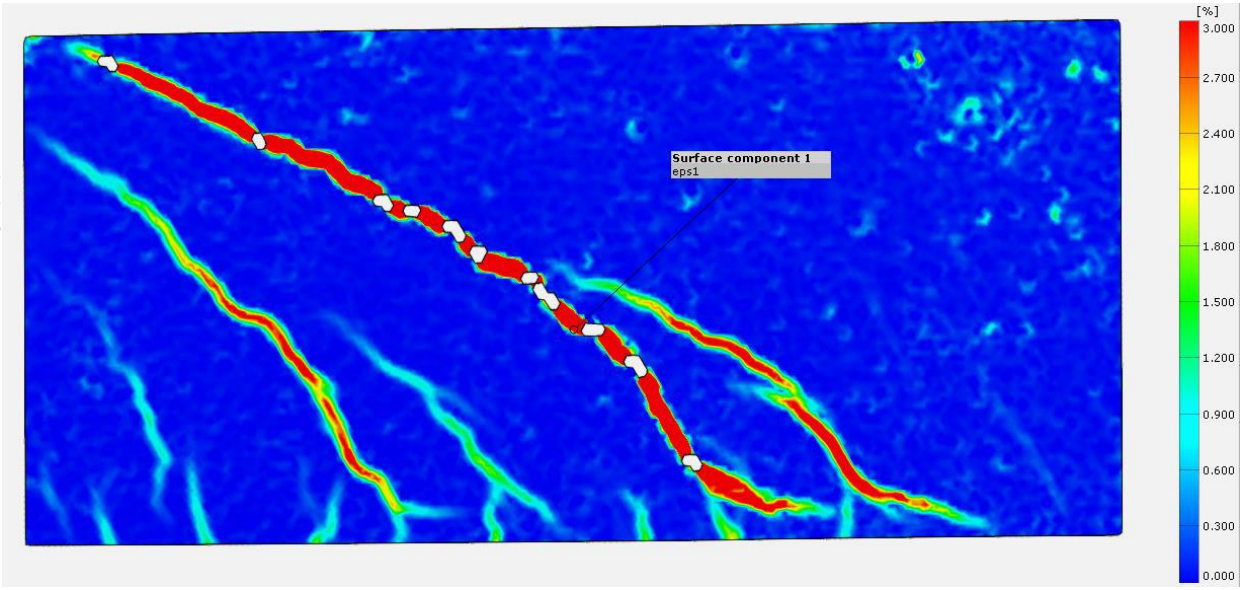


Recyled Aggregate Concrete

Ordinary Concrete vs. RAC: structural response



C35 – NAT



Research Team
UniSA-UFRJ

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Mayara **Amario**

Enzo **Martinelli**

Marco **Pepe**

Main Projects

EnCoRe Project: 2012-2014

Università di Salerno
Italy

Universidade do Minho
Portugal

Politecnico di Milano
Italy

Universidad de Buenos Aires
Argentina

Universidad Nacional de Tucuman
Argentina

Universidade Federal do Rio de Janeiro
Brazil

PEOPLE

MARIE CURIE ACTIONS

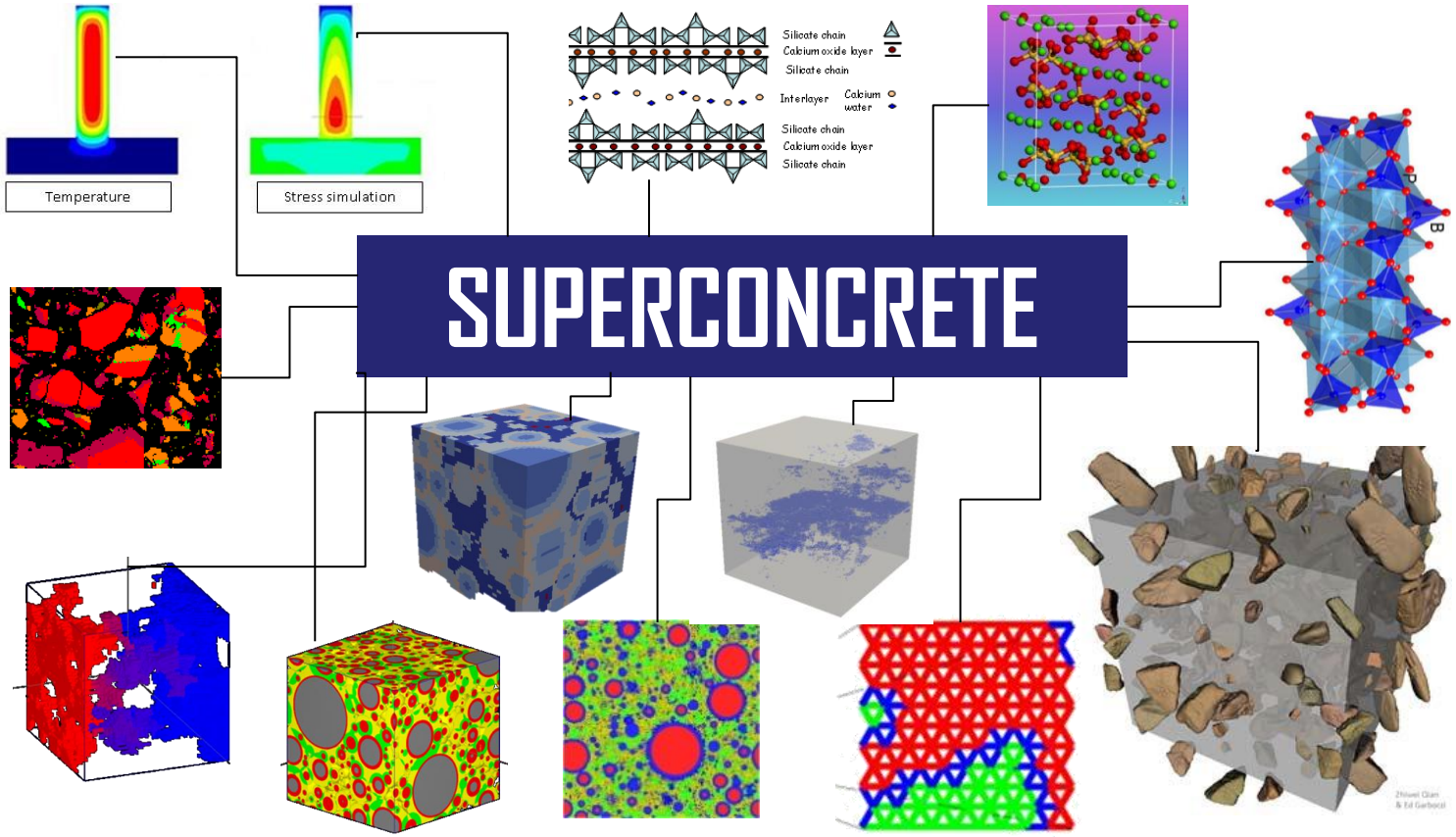
EnCoRe

ENvironmentally-friendly solutions for
COncrete with
REcycled and natural components

www.encore-fp7.unisa.it

Main Projects

SUPRECONCRETE Project: 2015-2019

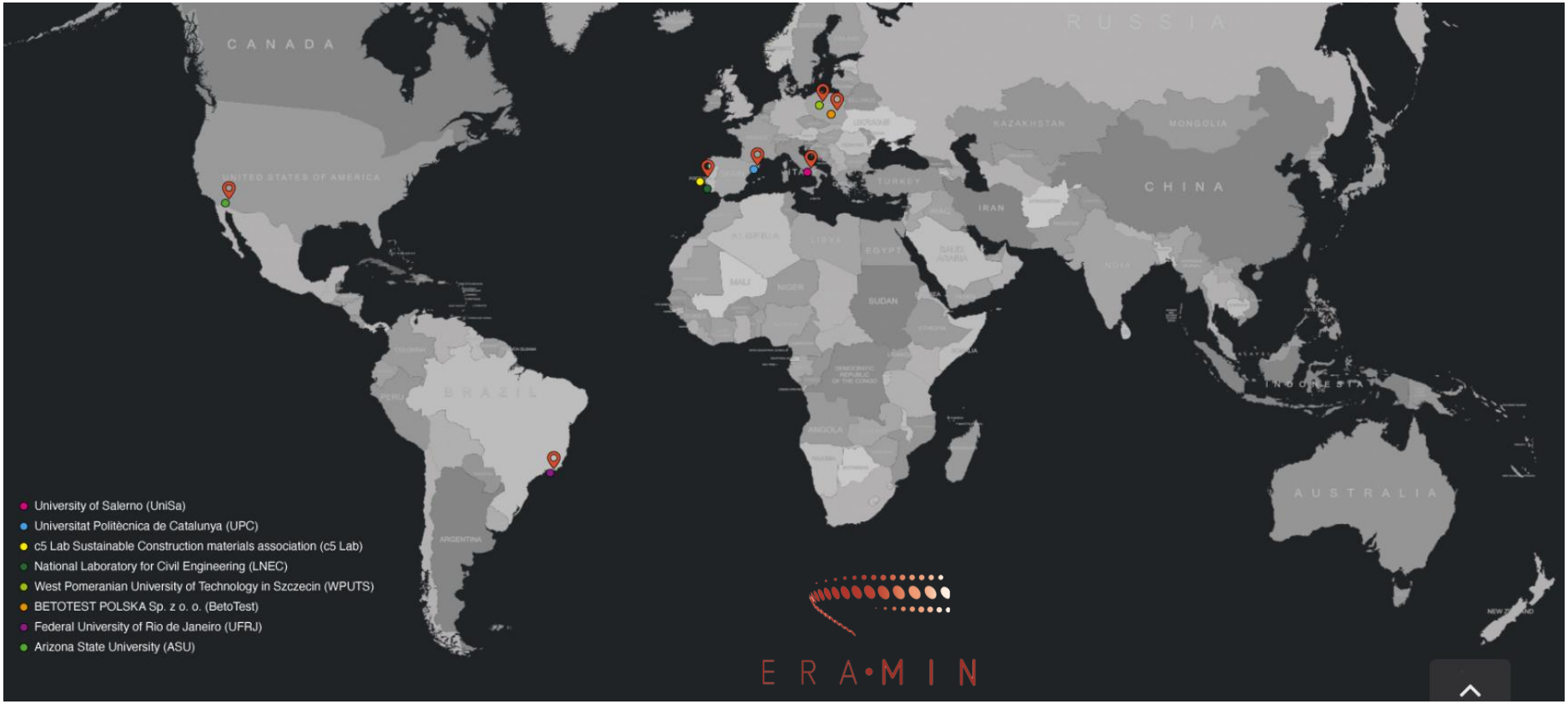


www.superconcrete-h2020.unisa.it

Main Projects

Recycl3D: 2022-2025

Recycled aggregates for **3D** printed concrete structures

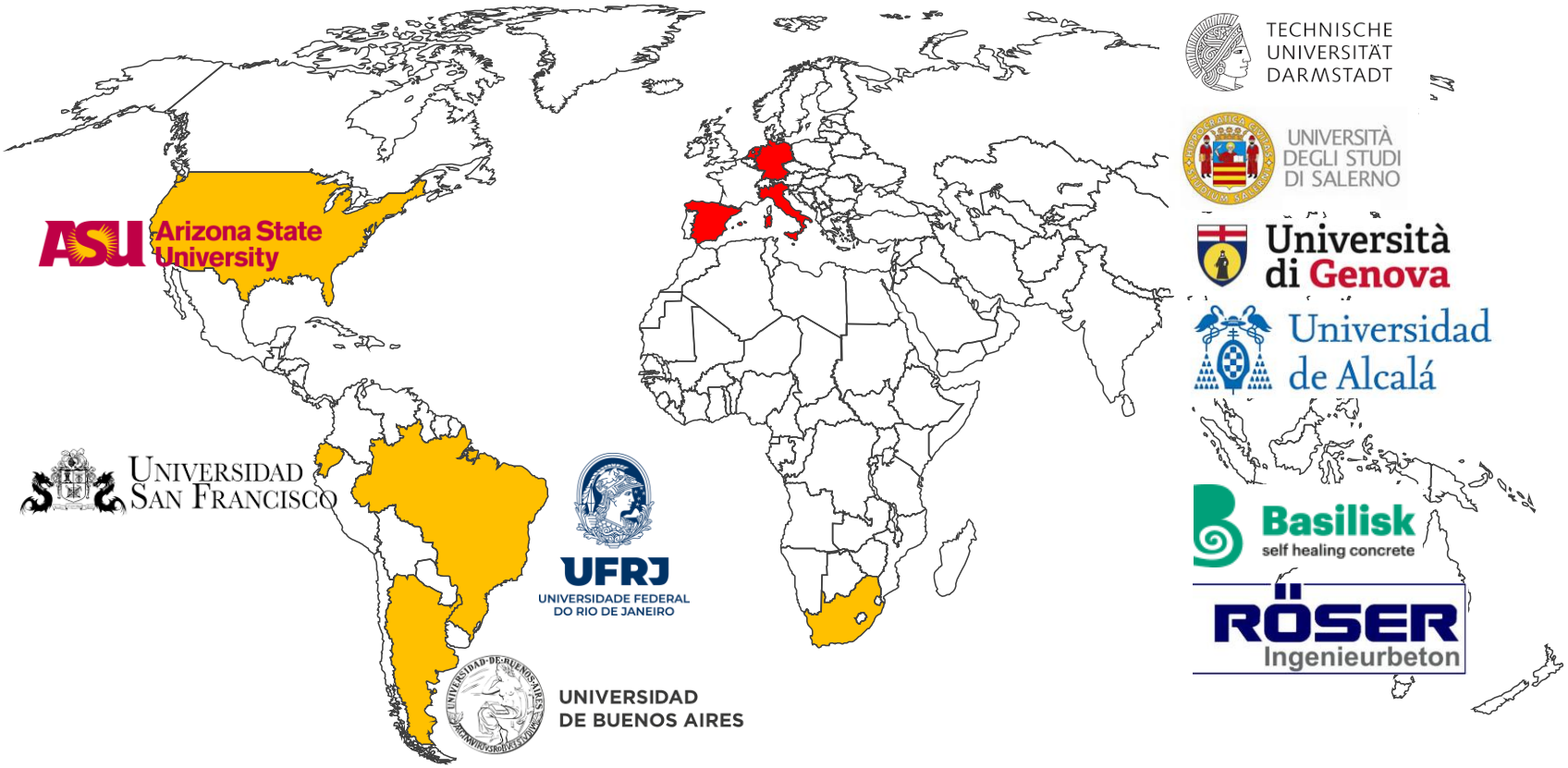


https://recycl3d.eu/

Main Projects

BEST: 2023-2027 (HE-MSCA-2021-SE-01)

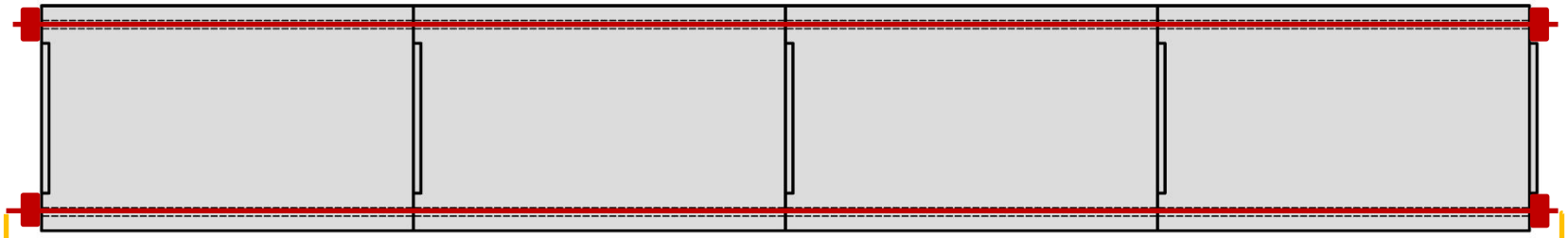
Bio-based **E**nergy-efficient materials and **S**tructures for **T**omorrow (GA: 101086440)



Main Projects

DeConStRACtion: 2022

Deconstructable Concrete Structures made of Recycled Aggregates from Construction & Demolition Waste



Main Projects

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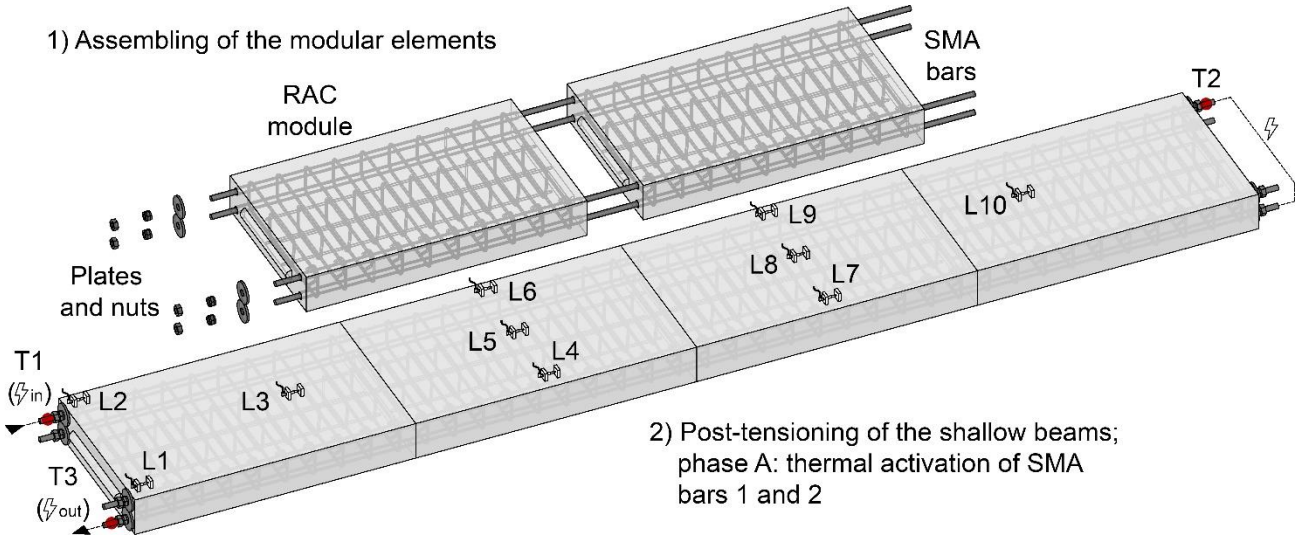
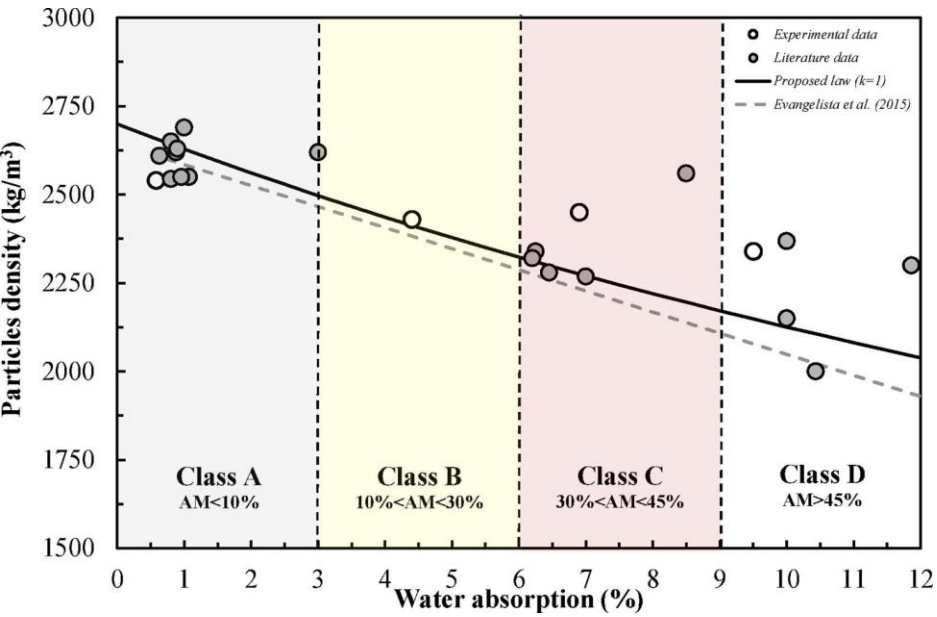


Main Projects
R3CoRD: 2023

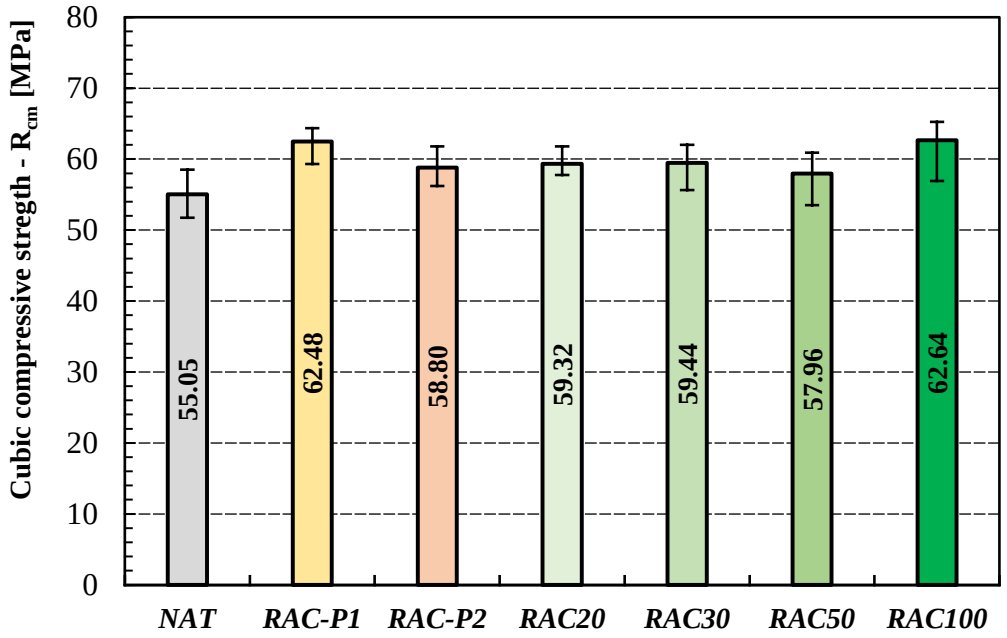
Recycling and 3D printing Concrete Research and Development



CIM UPC printer in Terrassa (Spain)

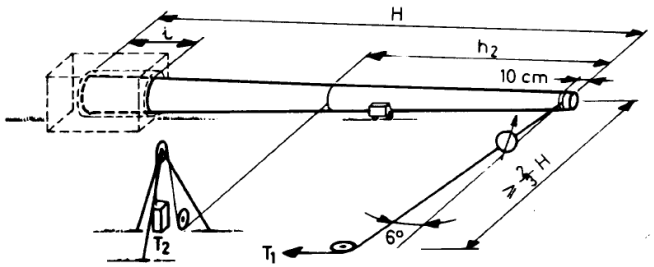
Main Projects

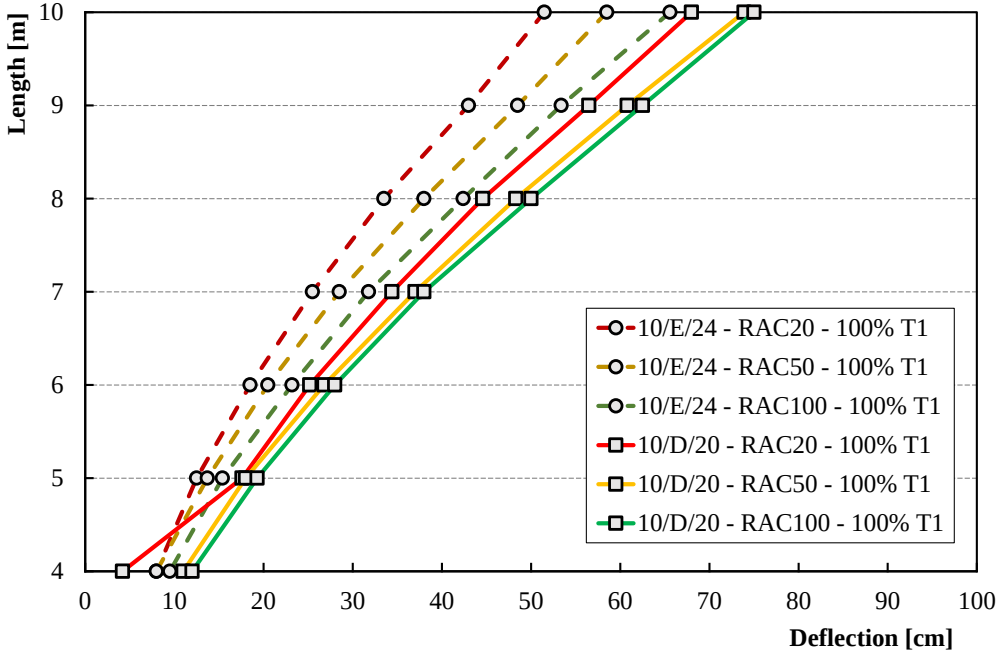
Centrifuged RC poles for electric power lines



Main Projects

Centrifuged RC poles for electric power lines





THE END

Thank you for your kind attention

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A rational approach to mix design

A comprehensive experimental campaign

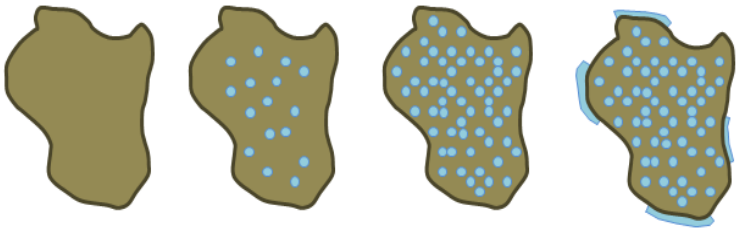
Aggregates replacement

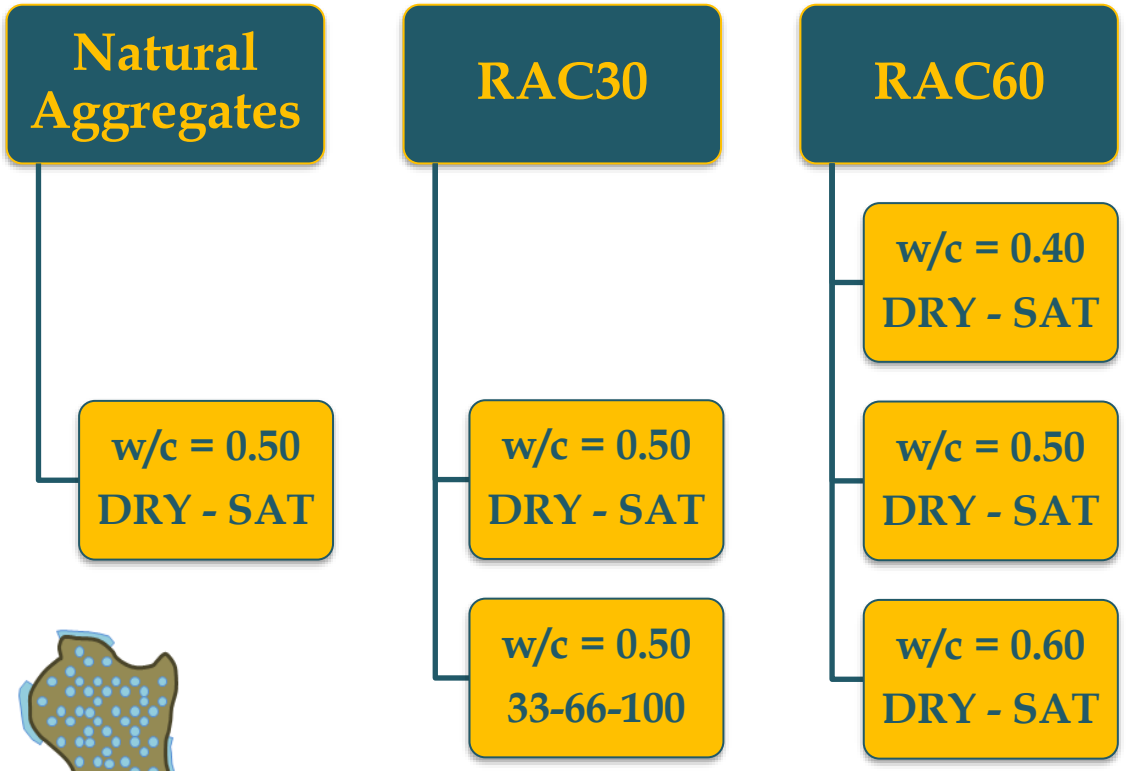
Water to Cement ratio

Initial moisture condition

Compressive strength

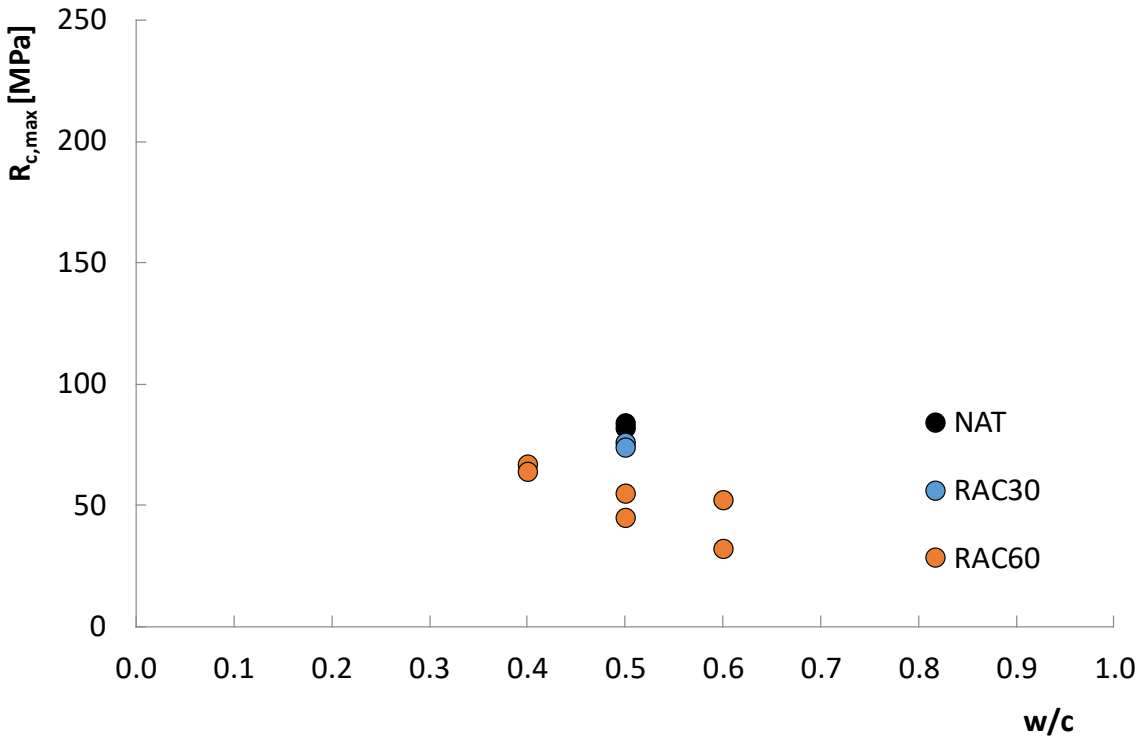
Temperature development





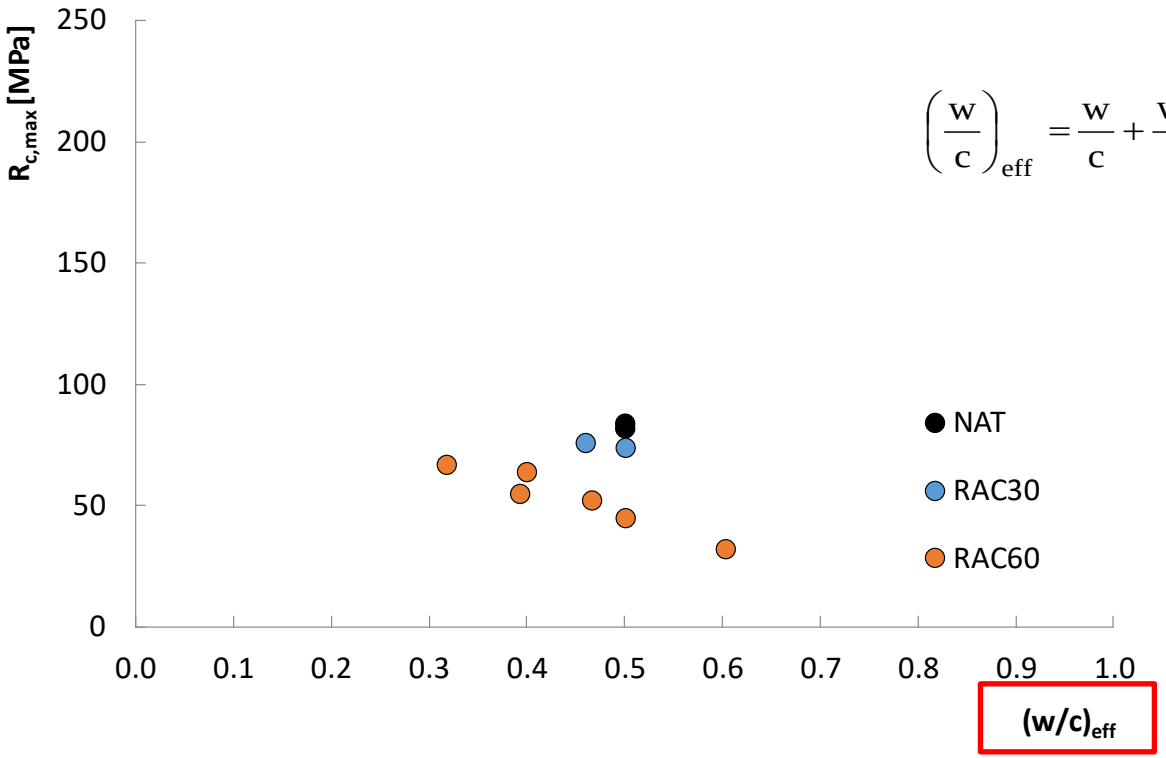
A rational approach to mix design

Towards a generalized Abrams' law/1



A rational approach to mix design

Towards a generalized Abrams' law/2



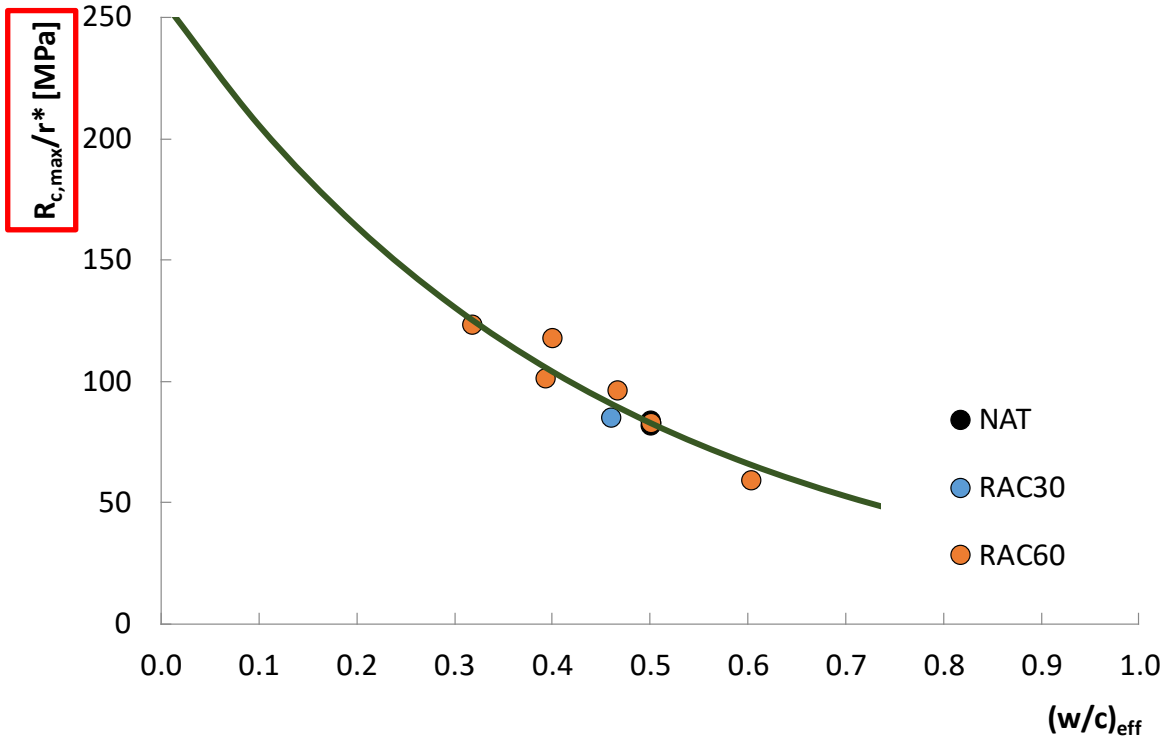
$$\left(\frac{w}{c}\right)_{eff} = \frac{w}{c} + \frac{w_{add}}{c} - \delta \cdot \left(\sum_{i=1}^{n} \frac{p_i \cdot P_i}{c}\right)$$

$$A_{MIX} = \sum_{i=1}^{n} p_i \cdot V_i$$

$$\frac{A_{NAT}}{A_{MIX}}$$

A rational approach to mix design

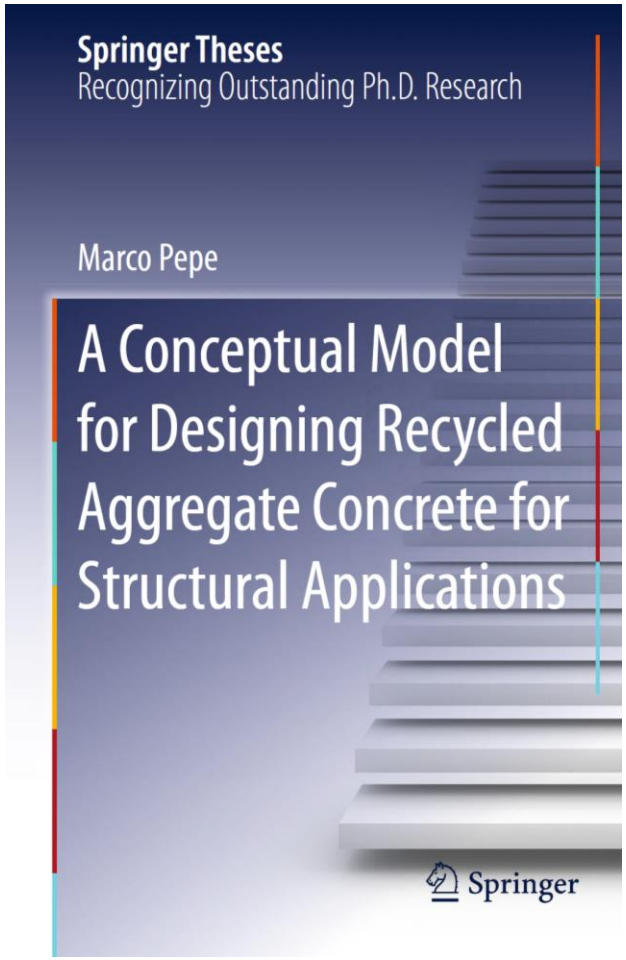
Towards a generalized Abrams' law/3

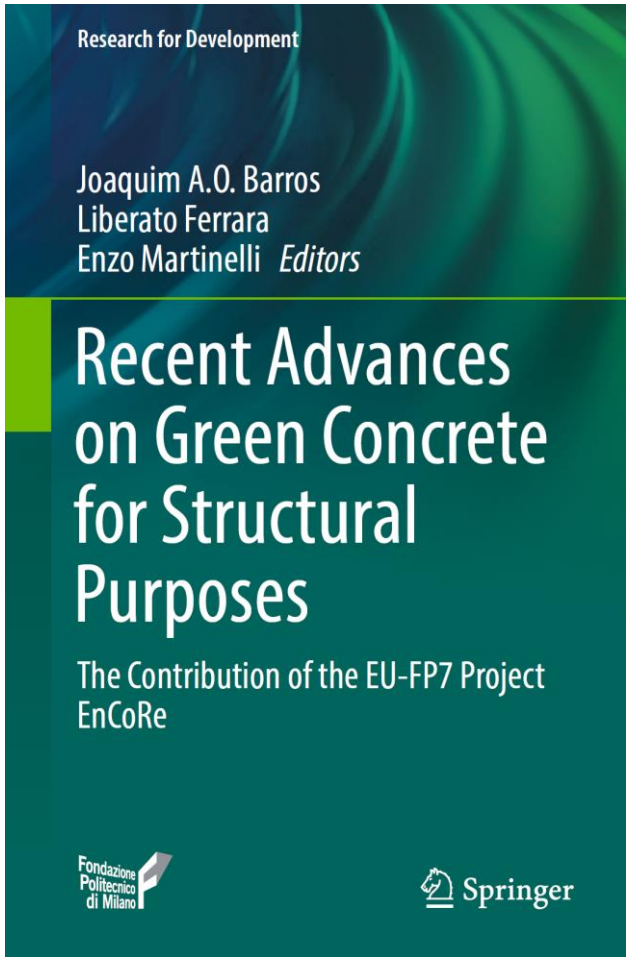


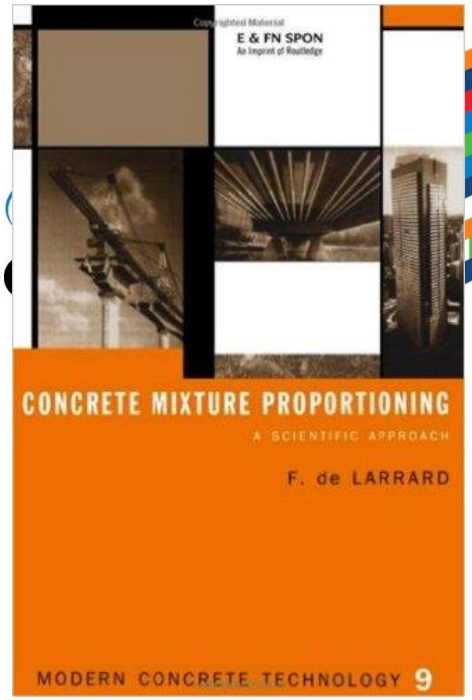
$$\frac{R_{c,max}}{r^*} = \frac{A_R}{B_R^{\,w/c_{eff}}}$$

Main Projects

EnCoRe Project: 2012-2014







Recyled Aggregate Concrete

Ordinary Concrete vs. RAC: compressive strength

Slump
S4: 160 mm – 210 mm

Strength
35 MPa – 60 MPa

Mixture	C1			C0			Sand	Cement	SP	Effective water	Total water	w/c
	NAT	RCA_L	RCA_D	NAT	RCA_L	RCA_D						
C35-NAT	452	0	0	457	0	0	868	325	1.86	196	212	0.60
C35-L-C0	451	0	0	0	373	0	866	338	1.93	194	217	0.57
C35-L-C1	0	361	0	456	0	0	867	336	1.92	191	216	0.57
C35-D-C0	451	0	0	0	0	371	866	345	1.97	191	214	0.55
C35-D-C1	0	0	384	453	0	0	862	341	1.95	194	216	0.57
C60-NAT	448	0	0	452	0	0	860	448	19.20	145	150	0.32
C60-L-C0	448	0	0	0	371	0	861	458	19.62	141	152	0.31
C60-L-C1	0	356	0	450	0	0	856	461	19.76	138	151	0.30
C60-D-C0	448	0	0	0	0	369	860	464	19.89	134	145	0.29
C60-D-C1	0	0	382	451	0	0	857	463	19.84	137	147	0.30

Recyled Aggregate Concrete

Ordinary Concrete vs. RAC: compressive strength