

Research posters eBook

according to 1st WORKSHOP

with Focus on experimental testing of cement-based materials held in Ljubljana, Slovenia, April, 16-17, 2015







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INTRODUCTION



About COST ACTION TU1404

Cement-based materials (CBM) are the foremost construction materials worldwide. Therefore, there are widely accepted standards for their structural applications. However, for service life designs, current approaches largely depend on CBM strength class and restrictions on CBM constituents.

Consequently, the service life behaviour of CBM structures is still analyzed with insufficiently rigorous approaches that are based on outdated scientific knowledge, particularly regarding the cumulative behaviour since early ages. This results in partial client satisfaction at the completion stage, increased maintenance/repair costs from early ages, and reduced service life of structures, with consequential economic/sustainability impacts.

Despite significant research advances that have been achieved in the last decade in testing and simulation of CBM and thereby predicting their service life performance, there have been no generalized European-funded Actions to assure their incorporation in standards available to designers/contractors.

The main purpose of COST TU1404 Action is to bring together relevant stakeholders (experimental and numerical researchers, standardization offices, manufacturers, designers, contractors, owners and authorities) in order to accelerate knowledge transfer in the form of new guidelines/recommendations, introduce new products and technologies to the market, and promote international and inter-speciality exchange of new information, creating avenues for new developments.



About 1st Workshop of COST ACTION TU1404

The Workshop was focused on specific tasks related to an extended Round Robin Testing (RRT+) organized within Workgroup 1 of COST ACTION TU1404. The following main objectives were:

- to make a scientific discussion on the proposed plan of RRT+ procedure and to allow the participants to provide their own comments/suggestions;
- to define of all the activities together with a detailed time schedule necessary to adequately start with the RRT+ procedure (i.e. to define transportation logistics, amount of basic materials that need to be transported to specific laboratory, etc.);
- to present the leaders of Group Priorities of WG1 and to allow them to express their ideas, demands, strategies, and expectations related to their GP in the form of short presentations;
- to allow other RRT+ participants to present some contributions relevant for a specific GP (e.g. their experiences related to previous RRT programs, etc.);
- to present expectations of WG2 and WG3 members related to the results of RRT+;
- to invite relevant speakers not included in COST ACTION TU1404;
- to allow the participants (i.e. members of RRT+) to present themselves, their organizations, their scientific work and contributions;
- to get acquainted with other RRT+ participants and WG members, etc.



About 1st Workshop of COST ACTION TU1404









Objectives of the posters

Two types of posters were presented at the Workshop, namely

- Institutional posters (type 1) and
- research posters (type 2).

The objective of type 1 posters was to present each institution participated at the Workshop which is necessary to know each other a little bit better and thus to achieve quality collaboration between the institutions included in the Action. Authors of the posters were therefore asked to provide the following main information:

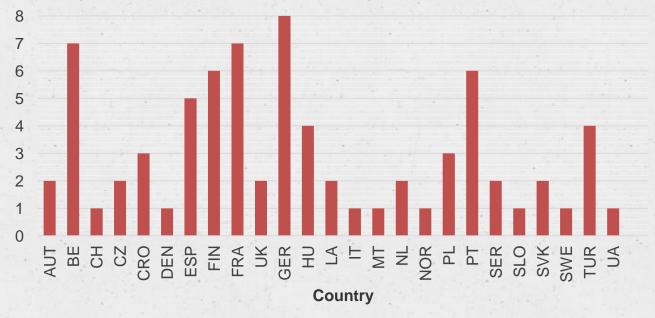
- (1) basic data of the organization including gender balance, number of young scientists and researchers, etc.,
- (2) main research equipment and testing techniques used to evaluate properties of cement based materials and concrete structures,
- (3) a list and (if possible) very brief presentation of potential self developed advanced testing techniques used to evaluate properties of cement based materials and concrete structures,
- (4) a role of the institution in this COST Action,
- (5) other information they consider important.



Some statistics...

- 63 institutions from 27 European countries were presented at the Workshop,
- 75 Research posters (type 2) were presented.
- Distribution of type 2 posters with respect to the participating countries is presented in the figure below:







RESEARCH POSTERS



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investigations

Experimental

Restraint stresses during life time considering hardening induced stresses



Dirk Schlicke¹⁾, Katrin Turner²⁾

1) Graz University of Technology, Institute of Structural Concrete, 2) Federal Waterways Engineering and Research Institute, Karlsruhe, Germany

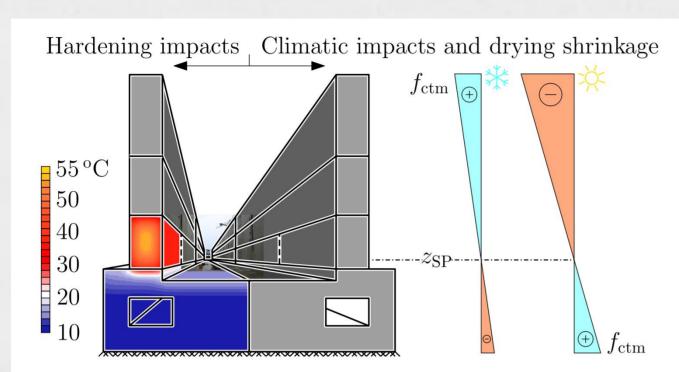
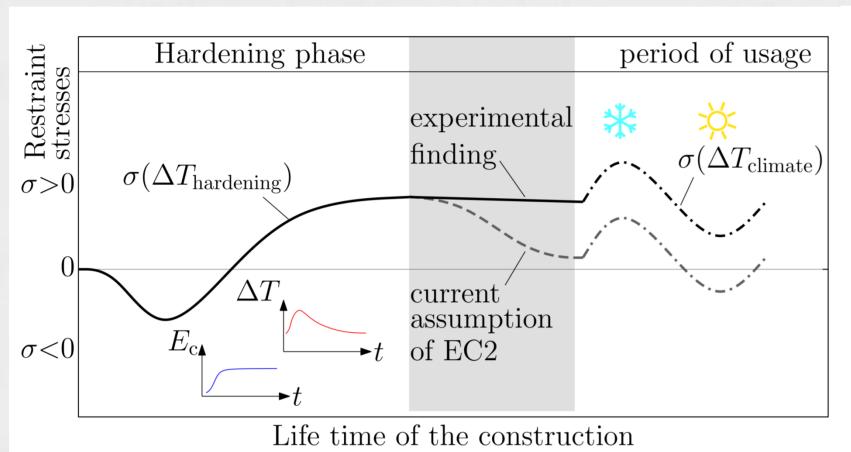


Fig. 1 Restraint stresses of concrete members

- development of an engineering model for explicit superposition of hardening induced restraint stresses with restraint stresses during service life
- mechanical based determination of minimum reinforcement for crack width control
- monolithic constructions / avoidance of dilation joints
 - fast building and cost-effective maintenance
 - robust structures





<top view >

Fig. 2 Stress history during life time

- SLS design with EC 2 simplifies the superposition of hardening induced restraint stresses with restraint stresses during life by the assumptions that
 - hardening induced restraint disappears due to relaxation in young concrete before they superpose with further restraint stresses during life time
 - additional restraint stresses during life time meet softened member stiffness if member already experienced hardening caused cracking
- increasing member thickness leads to mixed appearance of hardening induced stresses and restraint stresses of life time
- relaxation of hardening induced restraint stresses on tensile side cannot be observed with the conducted experiment

Experimental set-up (parallel testing with 2 set-ups) specimen $(l = 3.70 \,\mathrm{m})$

 $\boxtimes 4 \times \text{frictionless support}$

Fig. 3 Restraint frames at TU Graz

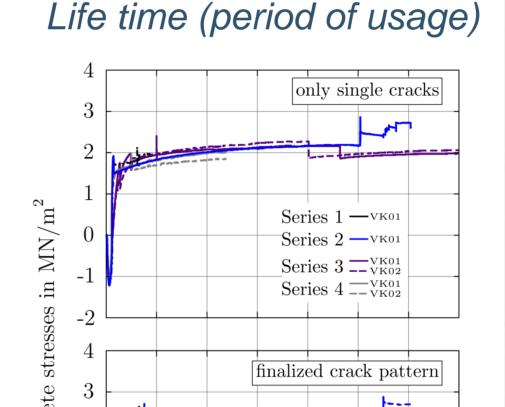
Stripping at T_{max} Temperature in $^{\rm o}{\rm C}$ 35 Series $2 = V_{VK02}^{VK01}$ 30 2520 insulation until $80\% \Delta T$ and $90\% \Delta T$ 15 Concrete stresses in MN/m^2 Crack Crack

Hardening phase

Fig. 4 Development of temperature and stress due to hydration (acc. to thermal conditions)

real time in weeks

1,5



real time in weeks Fig. 5 Influence of shrinkage and bond creep at different crack states

References

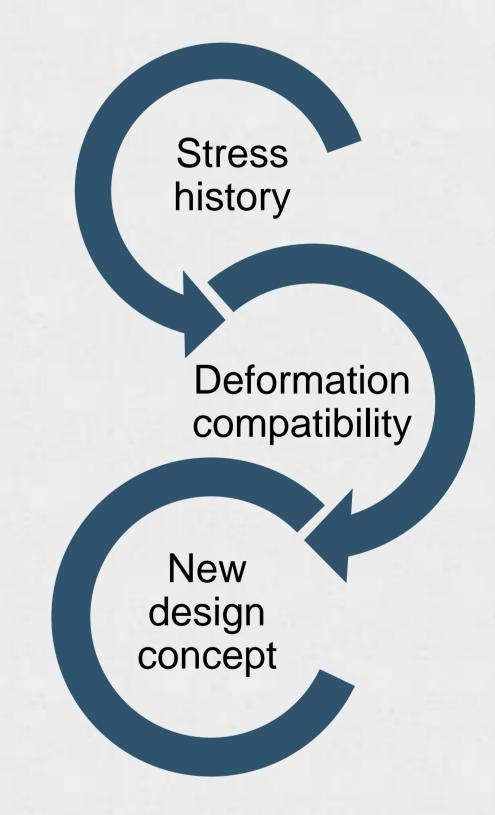
12

Series 1 -- VK02 Series 2 -- VK02

16

20

24



2,5

- [1] Turner, K.; Schlicke, D. and Tue, N.V.: Restraint and crack width development during service life regarding hardening caused stresses, Proceedings of fib 2015 symposium in Copenhagen.
- [2] Schlicke, D. and Tue, N.V.: Minimum reinforcement for crack width control in restrained concrete members considering the deformation compatibility, Structural Concrete 2015.
- Bödefeld, J.: Rissmechanik in dicken Stahlbeton-bauteilen bei abfließender Hydratationswärme. Mitteilungsblatt der BAW Nr. 92. 2010.
- Schlicke, Mindestbewehrung zwangbeanspruchter Betonbauteile unter Berücksichtigung der erhärtungsbedingten Spannungsgeschichte und der Bauteilgeometrie. Technische Universität Graz, Dissertation. 2014.

today's design assumption of a considerable relaxation of hardening induced restraint stresses cannot be verified

- only crack formation itself has a significant influence on the remaining hardening induced restraint stresses
- permanent durability may require an explicit superposition of restraint impacts of the production phase and the service life in some cases
- the effectiveness of insulation to reduce the risk of separating cracks due to outflow of hydration heat decreases with increasing member thickness









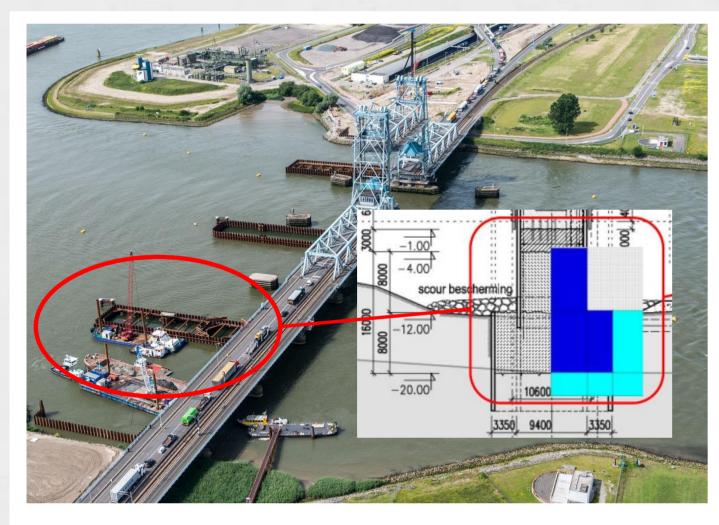
Efficient 3D-FEM Model for Simulation of Stresses Caused by Hardening in Large Concrete Structures

Peter Joachim Heinrich¹⁾

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Motivation

Typical mass concrete applications are foundations or hydraulic structures. The decisive stresses for design are usually restraint stresses caused by hardening. However, centric restraint or bending restraint might be of minor importance due to their dimensions [1]. This research focuses on the realistic quantification of the decisive stress distribution in order to allow an economic design.



Foundation of the New Botlek-Bridge (Netherlands)

Desired Results

- deep understanding of restraint stresses in hardening mass concrete structures to determine the decisive stress distributions for crack assessment (SLS) as well as superposition with load stresses (ULS)
- design concept for unreinforced mass concrete structures (in accordance with the safety philosophy of the EC2)

Acknowledgement

This research is funded by Austrian Research Promotion Agency (FFG), p-nr. 843489

References

[1] SCHLICKE, D. (2014).

"Mindestbewehrung zwangbeanspruchter Betonbauteile unter Berücksichtigung der erhärtungsbedingten Spannungsgeschichte und der Bauteilgeometrie." PhD-Thesis. Graz, University of Technology.

[2] HERMERSCHMIDT, W. and BUDELMANN H. (2014).

"Constitutive Law for the Viscoelastic Behaviour of Early Age Concrete in Massive Structures." RILEM International Symposium on Concrete Modelling, Bejing, pp. 183-189.

Approach Considering Real Material Behaviour

FEM Idealization

- fully parameterized
- finer mesh at the edges of the structure
- 3D volume elements (8 nodes with linear shape-functions)
- appropriate boundary conditions to consider symmetry as well as interaction with soil (thermal: heat storage; mechanical: vertical and horizontal restraining, see [1])

stress independent

properties for each element

 $(t_{eff}, E_c, \epsilon_{ca}, \ldots)$

Stress Independent Properties

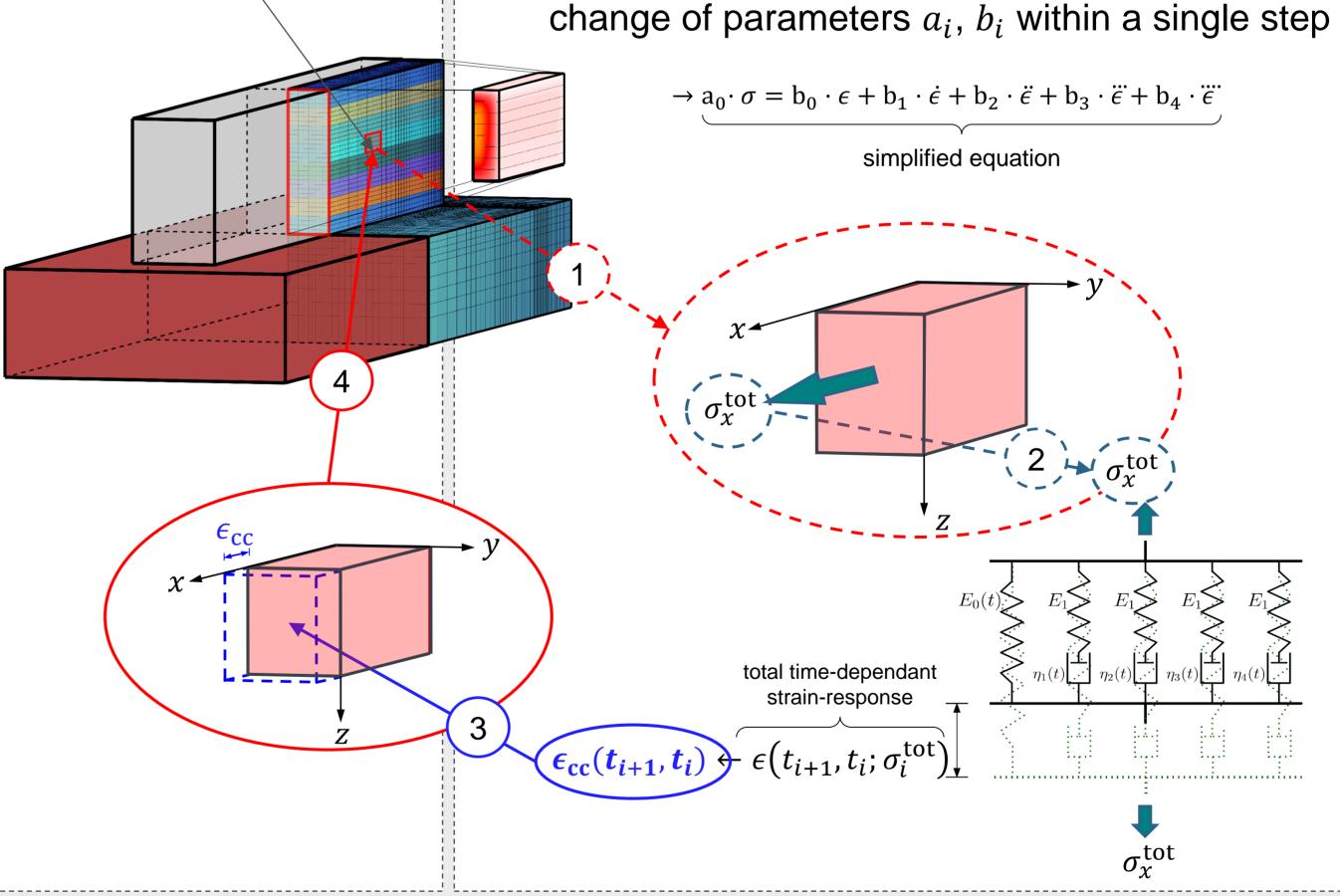
- modelling based on the effective concrete age:
 - hydration heat release with model of JONASSON
 - solid properties: Young's modulus and strength (compressive and tensile) with model of **WESCHE**
 - autogenous shrinkage ϵ_{ca} according to maturity

Stress Dependent Properties (Viscoelasticity)

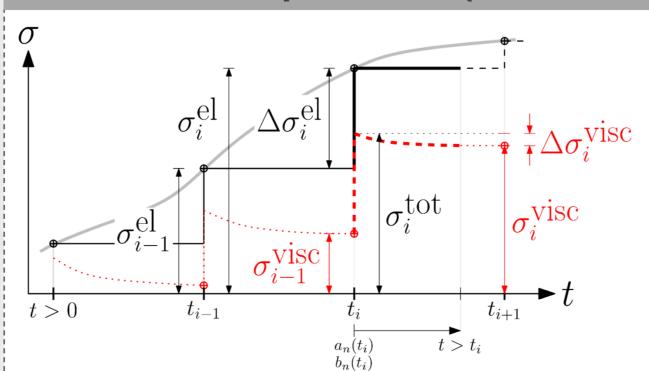
- viscoelasticity as additional deformation impact
- rheological body [2] (generalized MAXWELL model) describes deformation impact

$$a_0 \cdot \sigma + a_1 \cdot \dot{\sigma} + a_2 \cdot \ddot{\sigma} + a_3 \cdot \ddot{\sigma} + a_4 \cdot \dddot{\sigma} = b_0 \cdot \epsilon + b_1 \cdot \dot{\epsilon} + b_2 \cdot \ddot{\epsilon} + b_3 \cdot \ddot{\epsilon} + b_4 \cdot \dddot{\epsilon}$$

- parameters of the differential equation obtained by TSTM-tests [2] \rightarrow functions $a_i(t)$ and $b_i(t)$
- equation is solved analytically in every direction for each 3D element
 - requirement: small time-steps!
 - assumptions: neither change of stress σ^{tot} nor



Time-Step-Method (demonstrated with fully restraint 1D element)



remaining (viscoelastic) stress at a random point in time

$$\sigma_i^{\text{visc}} = \sigma_i^{\text{tot}} - \Delta \epsilon [(t_{i+1}, t_i); \sigma_i^{\text{tot}}] \cdot E_c(t_i)$$

with
$$\Delta\sigma_i^{\rm el}=\sigma_i^{\rm el}-\sigma_{i-1}^{\rm el}$$
 and $\sigma_i^{\rm tot}=\sigma_{i-1}^{\rm tot}+\Delta\sigma_i^{\rm el}$















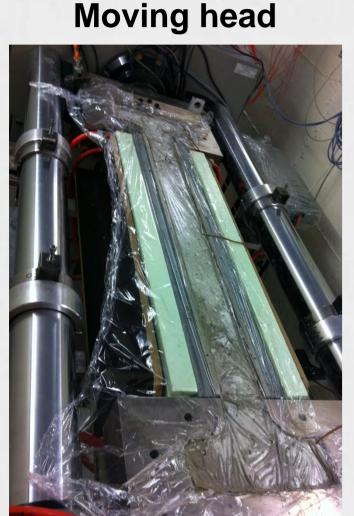


Laboratory of Civil Engineering – TU 1404 cost action WG1 and WG2

MONITORING AND MODELLING BASIC CREEP PROPERTIES OF **CEMENT BASED MATERIALS SINCE SETTING TIME**

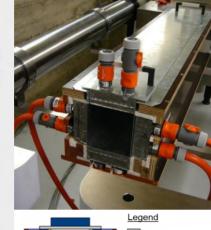
Brice Delsaute (bdelsaut@ulb.ac.be), Stéphanie Staquet (sstaquet@ulb.ac.be)

TSTM (Temperature Stress Testing Machine)



Fixed head

Measurement of displacement

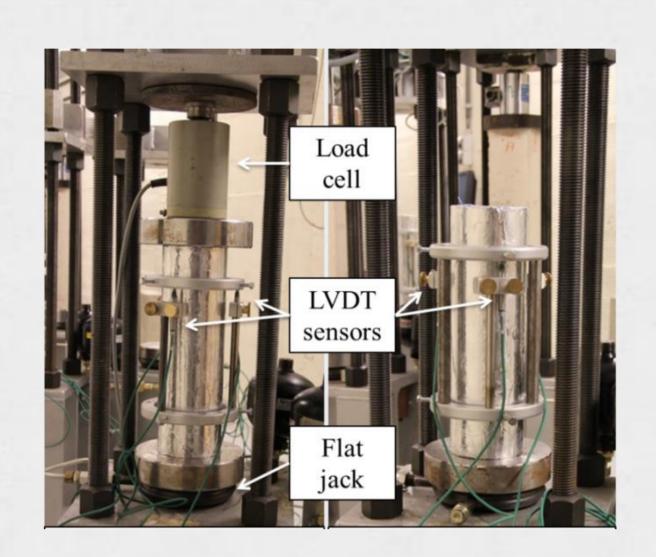




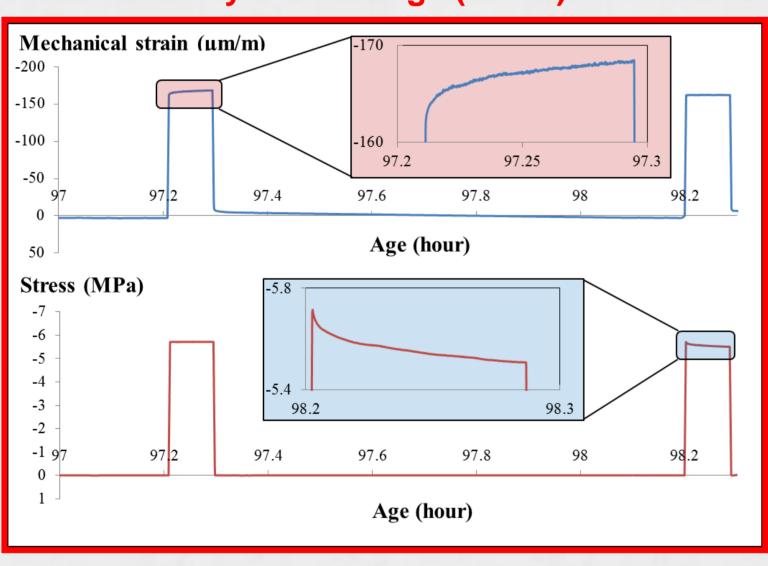
Free moving head

Fixed head

Compressive creep rigs (24)



Cyclic loadings (TSTM)

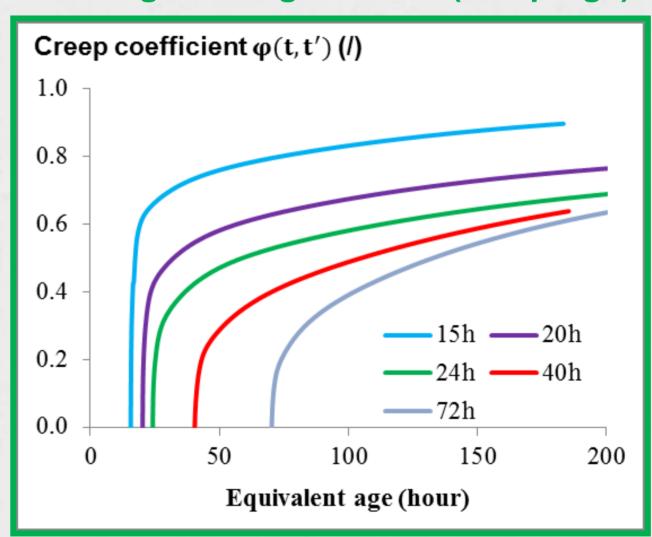


Monitoring of **E-modulus** (**E**) and very short term creep $(J_{VS}(t, t'))$

Creep compliance J(t,t')= $\frac{-}{\mathrm{E}(\mathrm{t}')} + \mathrm{J}_{\mathrm{VS}}(\mathrm{t},\mathrm{t}')$ $J_{S}(t,t') + J_{L}(t,t')$

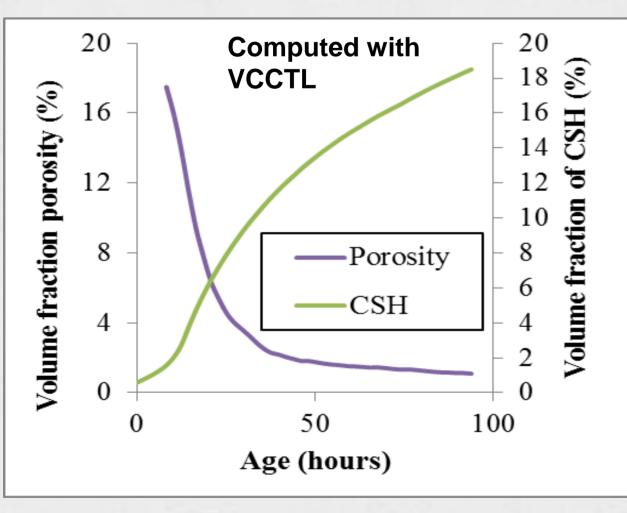
Monitoring of short term creep $(J_S(t, t'))$ and long term creep (J_L(t, t'))

Loadings of long duration (creep rigs)



Microstructural interpretation

Very short term and short term creep are linked to the capillarity pores and volume fraction of CSH



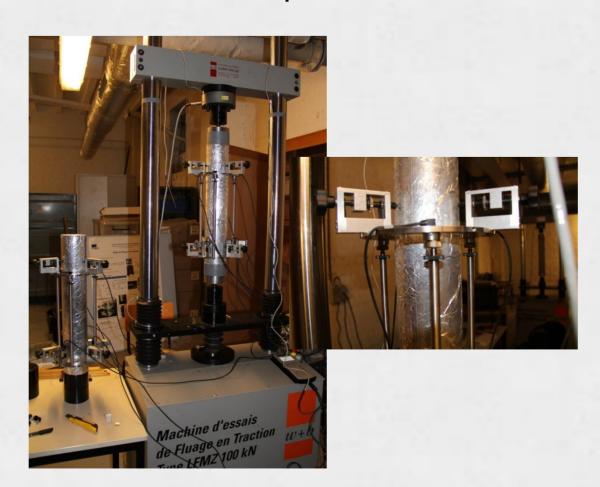
How to extend this study for concrete with high substitution of cement?



Looking for partners in the field of numerical simulation of microstructure including presence of supplementary materials

Experimental perspectives

- Compressive vs tensile creep
- High stress levels
- Realistic temperature conditions



Numerical perspectives

Integration of results in finite element modeling code



Jean-Michel Torrenti (jean-michel.torrenti@ifsttar.fr) Florent Baby (florent.baby@ifsttar.fr)

More information on http://batir.ulb.ac.be

Boulay, et al.: "How to monitor the modulus of elasticity of concrete, automatically since the earliest age", Materials and Structure, January 2014, Vol 47, pp141-155.

Delsaute, et al.: "Early age creep and relaxation modelling of concrete unde tension and compression", CONMOD2014, October 2014, Beijing

















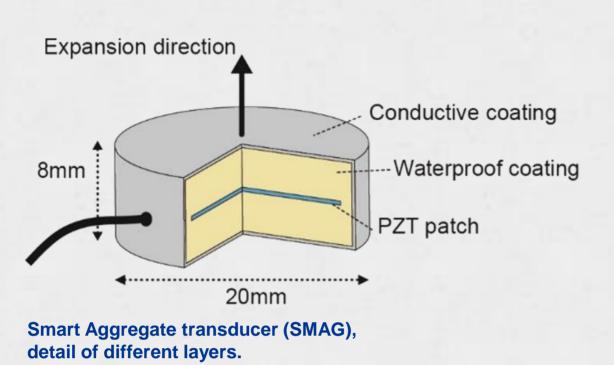
Laboratory of Civil Engineering – TU 1404 cost action WG1

IN SITU LIFE CYCLE MONITORING OF CONCRETE STRUCTURES USING EMBEDDED PIEZOELECTRIC TRANSDUCERS

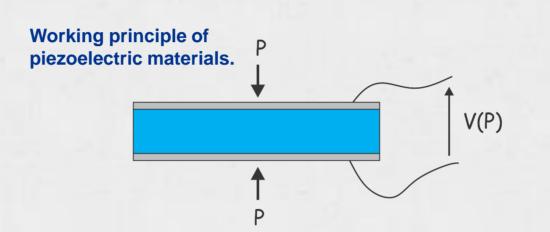
Cédric Dumoulin (cedumoul@ulb.ac.be), Arnaud Deraemaeker (aderaema@ulb.ac.be)

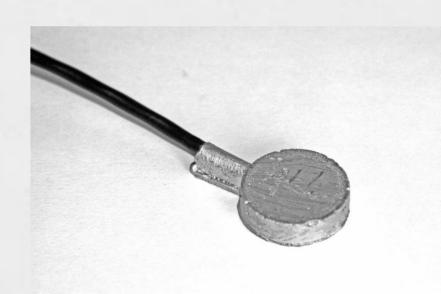
Smart Aggregates (SMAGs) are piezoelectric transducers which are embedded in a concrete structure in order to assess in real time the mechanical behavior of the concrete from very early age to potential damage, using ultrasonic techniques.

More information at batir.ulb.ac.be



The SMAGs manufactured at ULB-BATir are composed of a thin piezoelectric patch that enables to use the transducer both as ultrasonic actuator and sensor.





SMAG manufactured at ULB-BATir.

semi-direct

Ultrasonic Pulse velocity methods is currently one of the most widely used techniques for NDT in concrete. But, the use of large external probes strongly limits the measurement areas and only allows indirect ultrasonic measurements, which makes the interpretation uncertain.

The use of embedded transducers enables to overcome many drawbacks related to external transducers. They are not only potentially more efficient but they also add flexibility in the choice of their position, enhance their integration in the overall design of the structure and offers durability and protection from vandalism and environmental attack.

At early age, mechanical properties of concrete evolve continuously. Assessing the P-Wave velocity in real time can be used to evaluate the effective strength of concrete before removing formworks or applying the load in the case of

prestressed structures.



Prestressed structure (http://www.tucrail.be)

At high frequency the wave propagation is strongly affected by the microstructure of concrete and potentially by cracks. The damage appearance can therefore be detected by observing the wave which is transmitted from one SMAG used as emitter to another used as receiver.

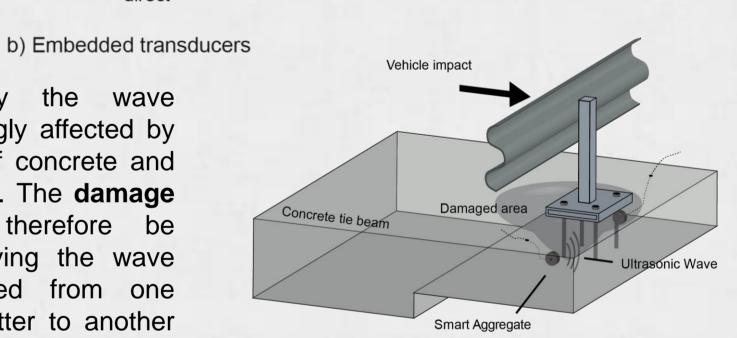
through thickness

E : Emitter

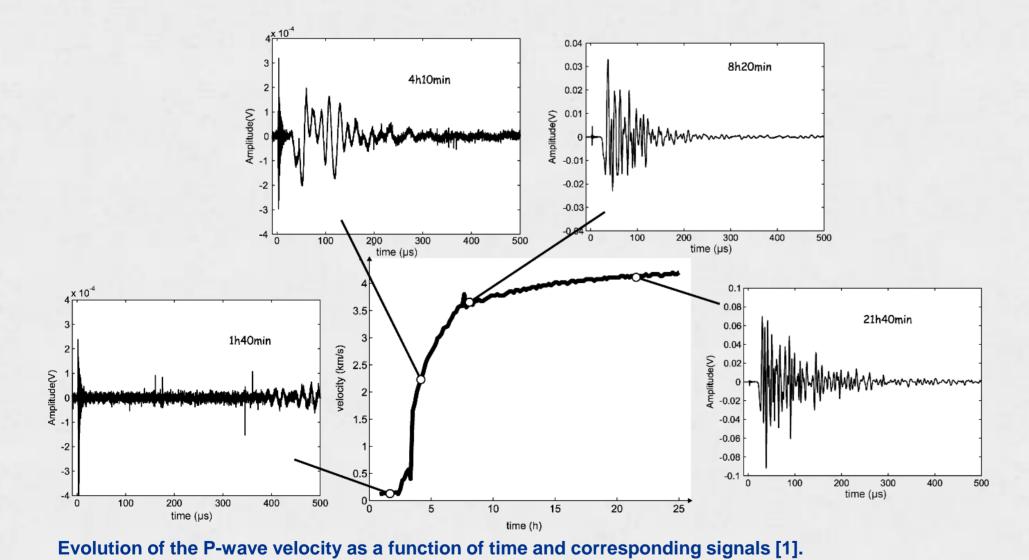
R: Receiver

Wave propagation in

UPV method.

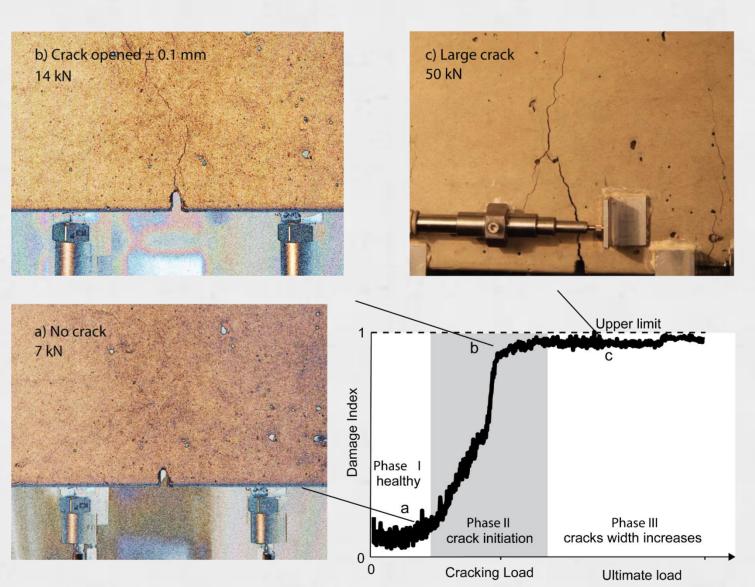


Bridge tie beam monitored by SMAGs.



[1] Dumoulin C, Karaiskos G, Carette J, Staquet S and Deraemaeker A 2012 Monitoring of the ultrasonic P-wave velocity in early-age concrete with embedded piezoelectric transducers *Smart Mater. Struct.* **21** 4 047001

[2] Carette J, Dumoulin C, Karaiskos G, Staquet S and Deraemaeker A 2012 Monitoring of the E-modulus in early age concrete since setting time with embedded piezoelectric transducers Proceedings of Structural Faults + Repair, 14th International Conference and Exhibition (Edinburgh, Scotland)



indirect

direct

a) External transducers

E □ "))

Evolution of the damage index with crack growth in a reinforced concrete beam [3].

- [3] Dumoulin C, Karaiskos G, Sener J-Y and Deraemaeker A 2014 Online monitoring of cracking in concrete structure using embedded piezoelectric transducers *Smart Mater. Struct.* **23** 11 115016 (10pp)
- [4] Dumoulin C and Deraemaeker A 2014 Real-time fast ultrasonic monitoring of cracking in a concrete cylinder subject to compression 9th International Conference on Structural Dynamics, EURDODYN 2014 (Porto, Portugal) pp 1–5

This research is supported by











Construction materials from stainless steel slags by alkali activation

Muhammad Salman¹, Özlem Cizer¹, Yiannis Pontikes², Lucie Vandewalle¹, Bart Blanpain², Koen Van Balen¹
¹KU Leuven, Civil Engineering Department, Belgium; ²KU Leuven, Materials Engineering Department, Belgium

Objective:

To find sustainable solutions for the valorization of continuous casting (CtCs) and argon oxygen decarburization (AOD) stainless steel slags in the form of construction materials.

Approach:

- Exploit the binding potential of the slags by alkali activation
- Study the effect of alkalis on the slag mineralogy and microstructure during hydration
- Produce prototypes simulating the construction materials available in the market

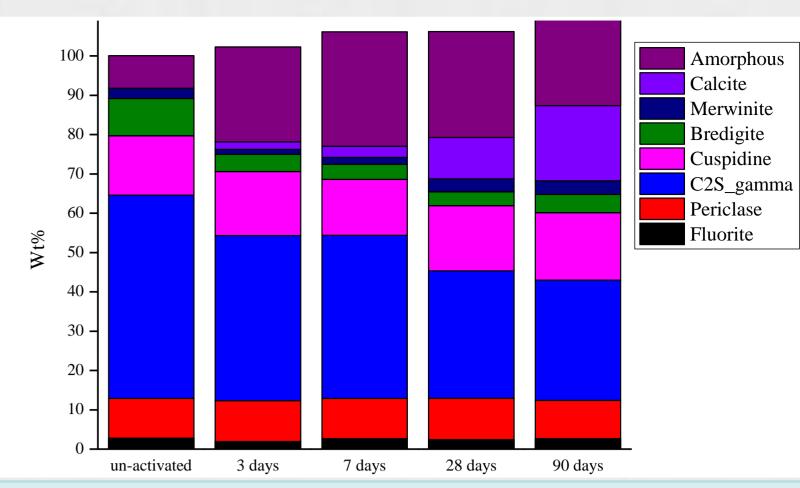


Fig.1. QXRD analysis of hydrated slag at different ages shows changes in slag mineralogy due to alkali activation

Results:

Alkali-activation of CtCs and AOD slags under steam curing can produce end products which have potential to be used as building blocks and bricks in construction applications with reduced environmental impact. The compressive strength of the products improve with the amount of silicates and curing temperature.

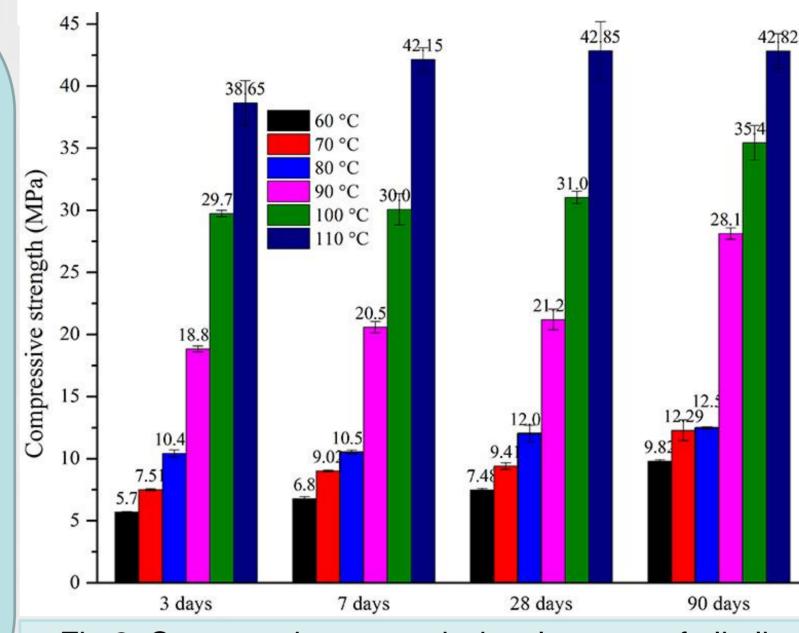


Fig.2. Compressive strength development of alkali activated CtCs stainless steel slag mortars at different steam curing temperatures up to 90 days

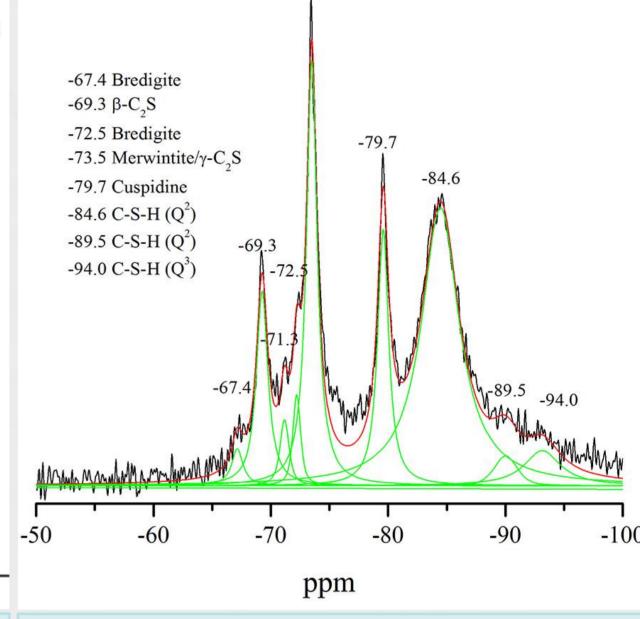


Fig.3. ²⁹Si MAS NMR of alkali-activated stainless steel slag showing reaction products as a result of hydration

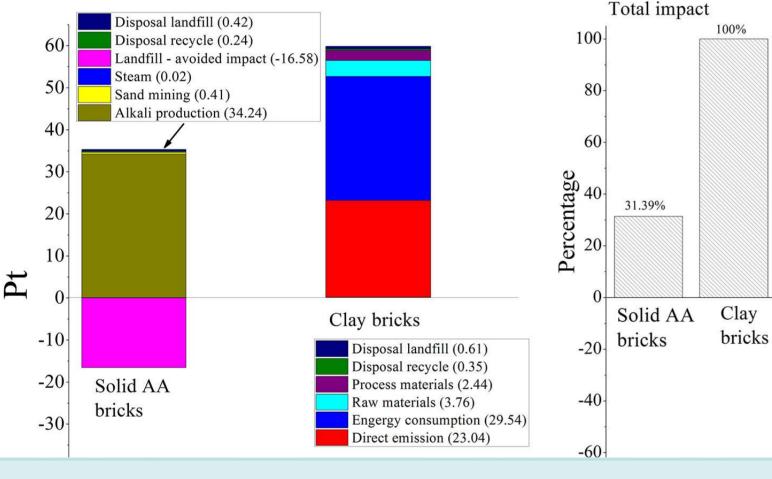


Fig.4. Life cycle analysis of alkali activated (AA) bricks shows lower impact than the traditional clay bricks

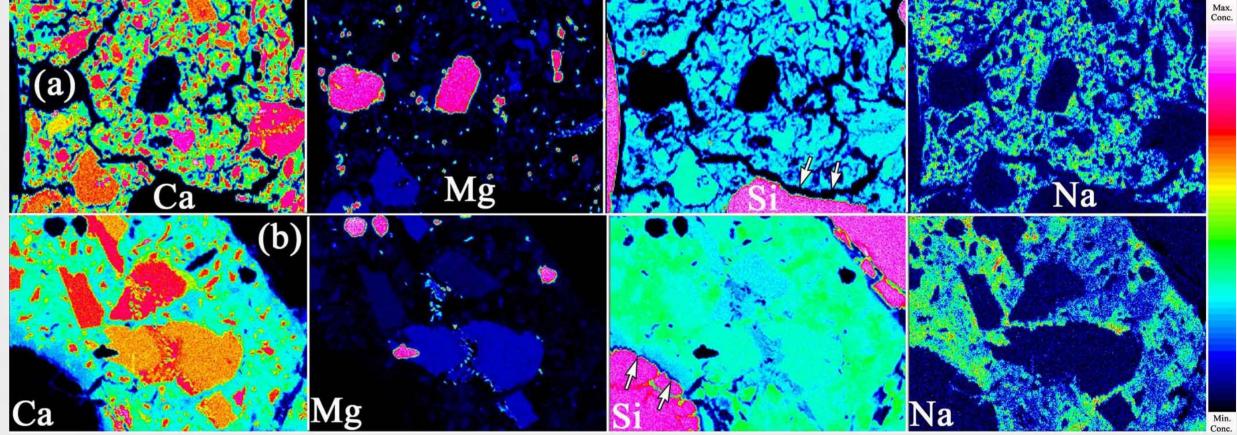
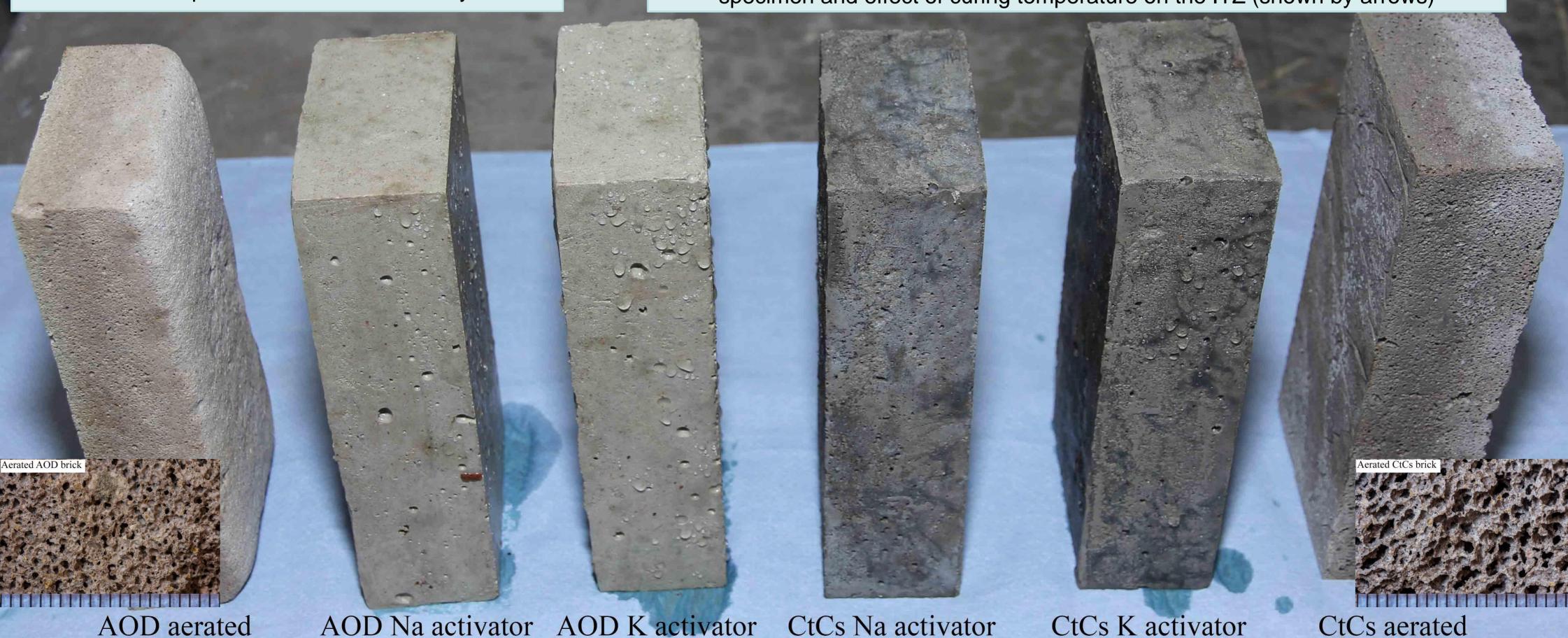


Fig.5. Elemental mapping of alkali activated stainless steel slag at (a) 60 °C and (b) 110 °C showing distribution of different elements across the hydrated matrix of the specimen and effect of curing temperature on the ITZ (shown by arrows)









Construction materials from stainless steel slags by accelerated carbonation

Muhammad Salman¹, Özlem Cizer¹, Yiannis Pontikes², Lucie Vandewalle¹, Bart Blanpain², Koen Van Balen¹
¹KU Leuven, Civil Engineering Department, Belgium; ²KU Leuven, Materials Engineering Department, Belgium

Objective:

To find sustainable solutions for stainless steel slags in the form of construction materials.

Approach:

- Exploit the binding potential of the slag by accelerated carbonation
- Study the effect of different accelerated carbonation techniques on the slag mineralogy and morphology
- Produce prototypes simulating the construction materials available in the market

Results:

Stainless steel slags, due to its alkaline nature and availability as fines, has potential to act as carbon sink. The carbonated material can achieve compressive strengths required for most construction applications. Since accelerated carbonation results in the carbonation of only a fraction of the slag, the resulting products can act as carbon sinks during their service life. Different carbonation conditions results in various forms of carbonate phases in the slag. Life cycle analysis (LCA) shows that the perforated bricks produced form carbonated slags have much lower environmental impact than the conventional clay bricks.

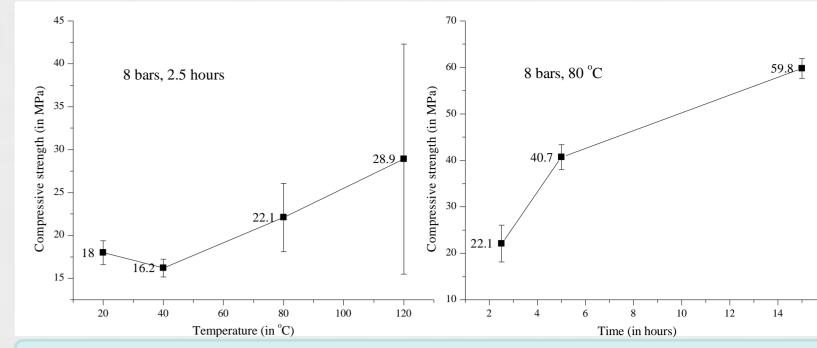


Fig. 1. Compressive strength of carbonated slag

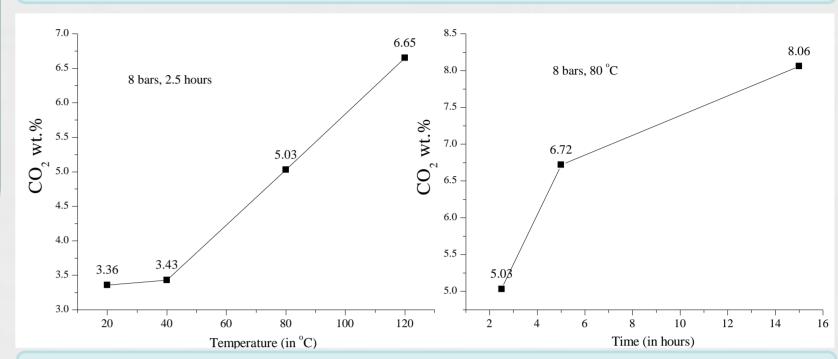


Fig. 2. Fraction of CO₂ captured in carbonated slag

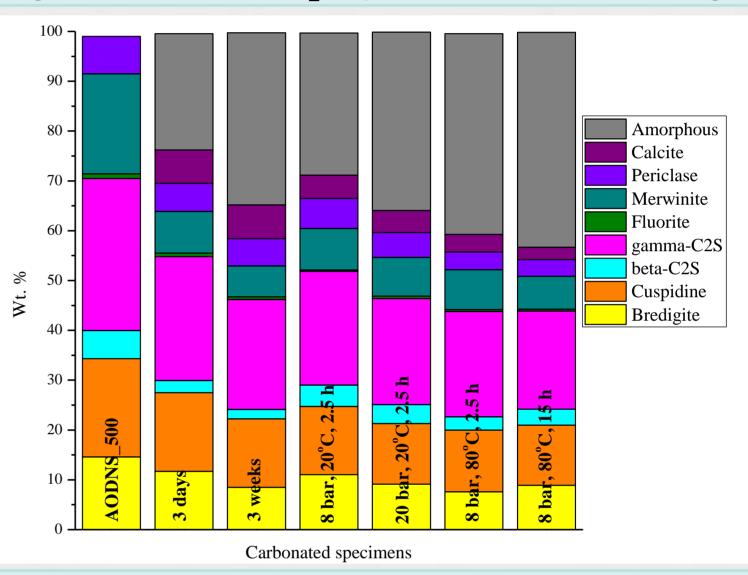


Fig. 3. QXRD analysis giving phase compositions of slag specimens carbonated at different conditions

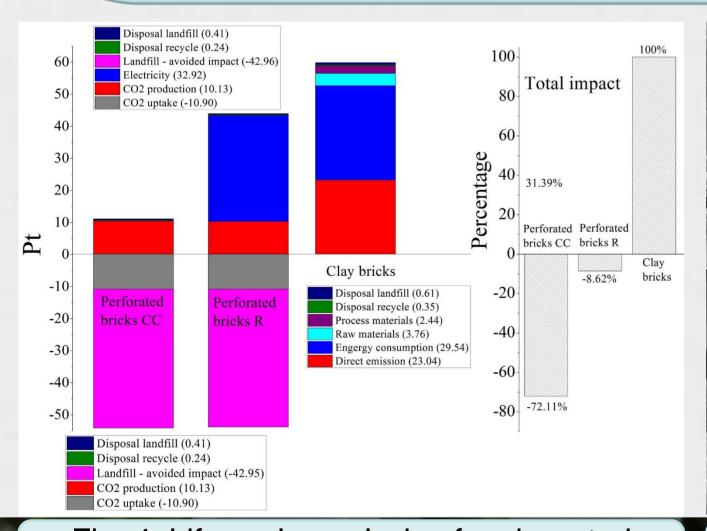


Fig. 4. Life cycle analysis of carbonated slags compared to traditional clay bricks

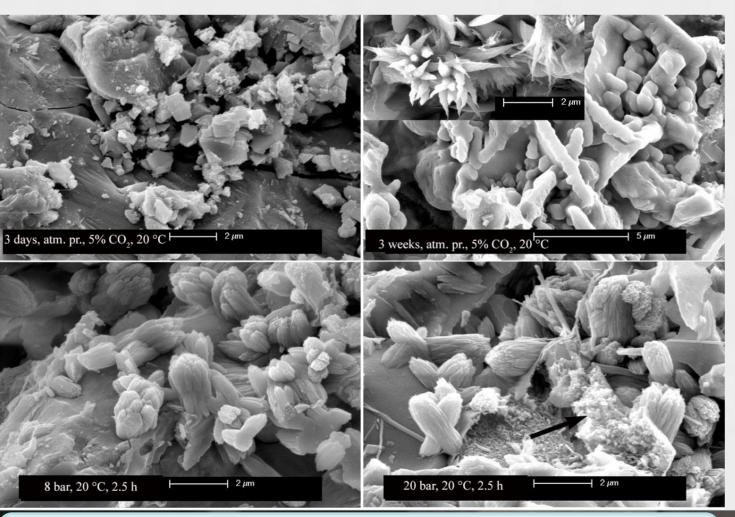


Fig. 5. Different morphologies of carbonate forms in carbonated stainless steel slag

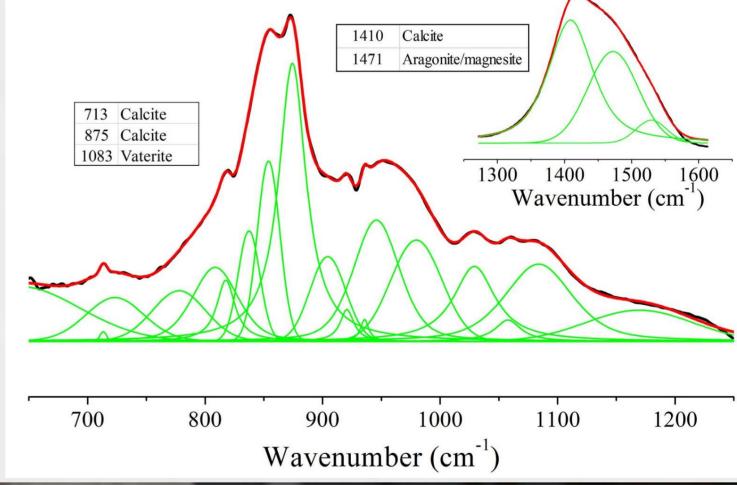


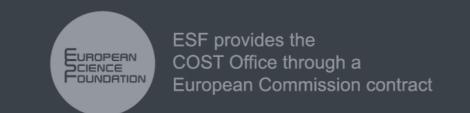
Fig. 6. Carbonate phases in stainless slag by FTIR analysis



Carbonated CtCs bricks

Carbonated AOD bricks











Concrete and Environment

Test equipment

Prof. dr. ir. Nele De Belie

Green concrete

- Use of by-products
 - Fly ash
- MSWI ashes
- Slag
- Copper slag
- Silica fume
- Portland clinker out of secondary or recycled materials
- Completely recyclable concrete



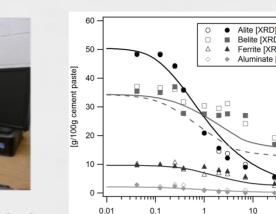
Materials and reactions

Microstructure

Dural



Laser diffraction analysis



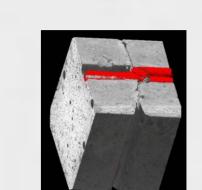
XRD analysis



Isothermal calorimetry

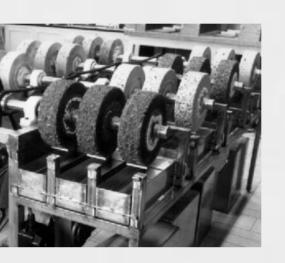


Non-destructive testing of early-age concrete with ultrasound





Scanning electron X-ray tomography microscope



Air permeability

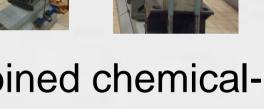
tests

Accelerated degradation tests



Chloride diffusion tests





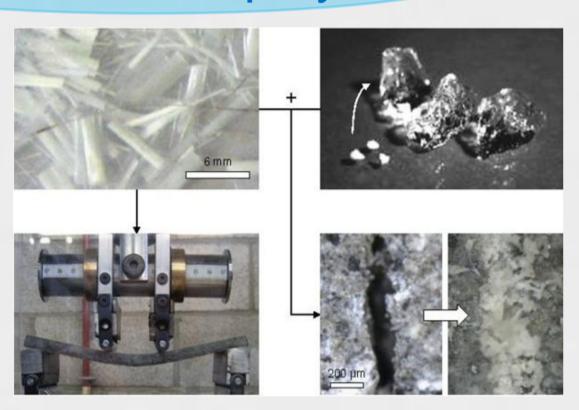
Combined chemicalmechanical attack

Self-healing concrete

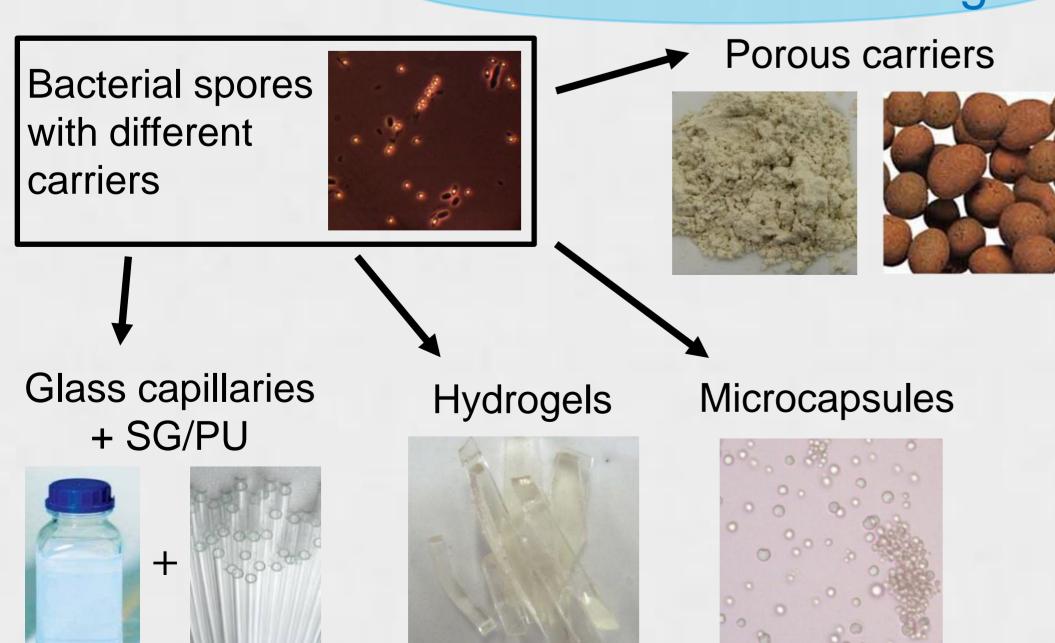
Superabsorbent polymers

Combination of fibres and hydrogels

Crack closure by further hydration & CaCO₃ precipitation



Bacterial self-healing



Encapsulated polymers

Elastic polyurethane as healing agent







Compatibility/durability of the capsules



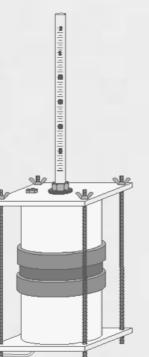
- Survival of mixing process
- Breakage upon crack formation

Test equipment

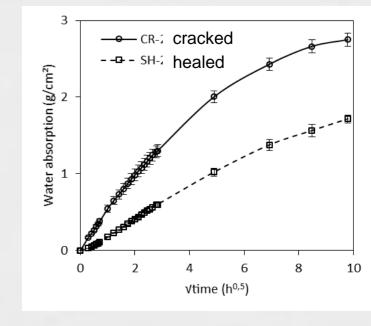
3- and 4-point bending to create cracks



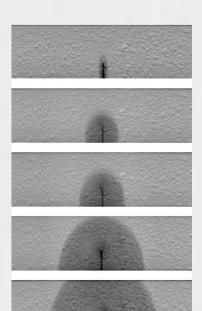




Water permeability & water absorption tests



X-ray radiography













ADVANCES IN MICROSTRUCTURE CHARACTERISATION TECHNIQUES

Ruben Snellings ruben.snellings@vito.be

Sustainable Materials Management, VITO



Preparing for a diverse future - needs for microstructural characterisation

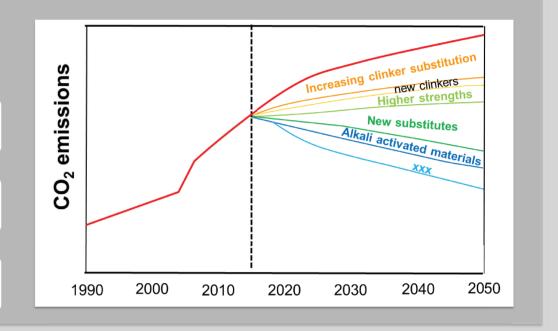
Pressing for change - accommodating the great leap forward

Increasing societal and political pressure for change: reductions in CO₂ emissions - increase recycling of residues (zero waste)

Opportunities for diversification - development of a wide range of alternative binders: new SCMs, CSA-cement, alkali-activated cements, carbonate cements,...

Durability of these new materials is not well-understood - current standards and service life models applicable?

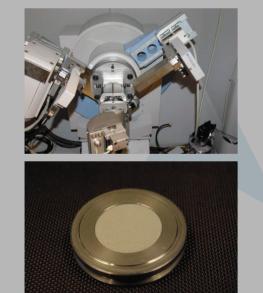
Need for microstructural studies and expertise to 1) track and identify issues and 2) describe and understand the occurring phenomena as a basis for mechanistic modelling



X-ray diffraction

Hydrate assemblage characterisation

- · Standard technique for hydration studies: kinetics, changing hydrate assemblages as a function of binder composition
- Fast, wealth of information, easy sample preparation, analytical expertise needed
- Regular Rietveld analysis: quantification of crystalline phases
- PONCKS (Partial Or No Known Crystal Structure): extension to calibrated amorphous phases



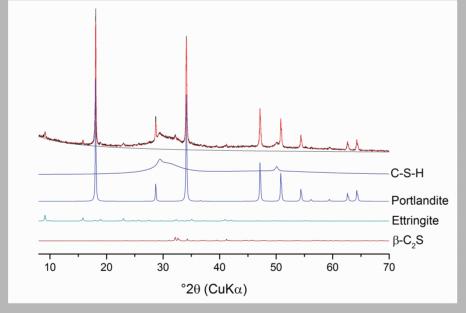
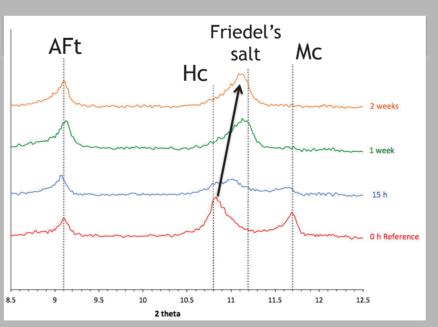
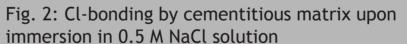


Fig. 1: XRD pattern decomposition by Rietveld - PONKCS analysis. 7 years hydrated White Portland cement

Analysis of deterioration mechanisms

- Bonding vs. Leaching mechanisms can be assessed
- · Deterioration kinetics experimental data for comparison and calibration of durability models
- Chloride/sulfate attack depth profiling studies penetration depths
- Sensitive to changes in AFm/AFt hydrate assemblages





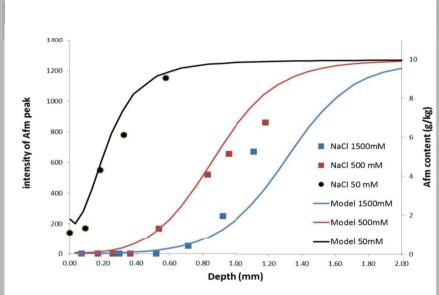


Fig. 3: Experiment and modelling (Stadium®) of hydrate assemblage response to chloride attack (courtesy P. Henocq)

Electron microscopy

Hydrate assemblage characterisation

- Standard microstructure characterisation technique powerful when combined with EDX and image analysis:
 - Phase quantification: distinction among different amorphous phases (e.g. in fly ashes - Fig. 4)
 - Compositional changes of hydrates as a function of binder composition (e.g. C-A-S-H phase - Fig. 5)

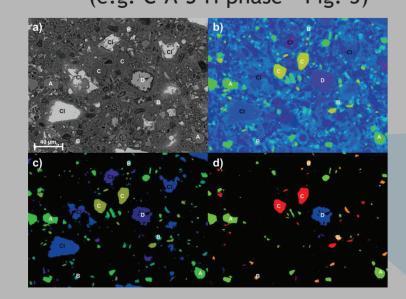


Fig. 4: Image analysis of BSE (a), EDXmappings (b): hydrate thresholding (c), followed by segmentation based on chemical composition of anhydrous phases in fly ash blended cement (PhD P. Durdzinski)

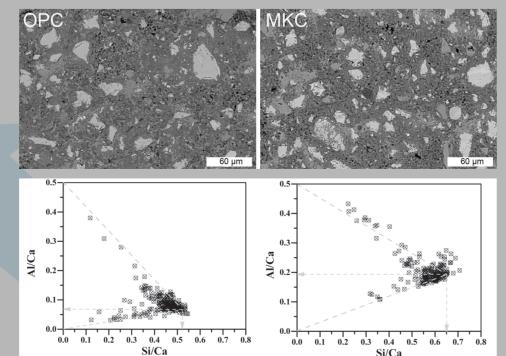


Fig. 5: BSE images and EDX point analysis plots to determine C-S-H composition in a Portland cement (left) and metakaolin blended cements (right)

Analysis of deterioration mechanisms

- Visualisation of damage and underlying deterioration mechanisms - powerful when combined with EDX and image analysis:
 - Quantification of extent of reaction/damage (e.g. ASR - Fig. 7)
 - Changes in composition of the cementitious binder caused by chemical attack

(e.g. Sulfate attack - Fig. 8)

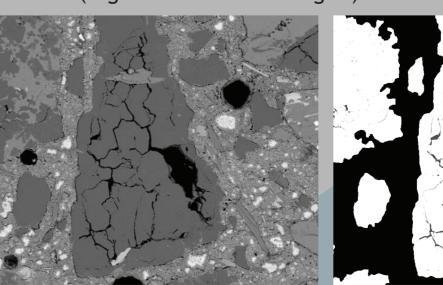


Fig. 7: BSE image of ASR affected aggregate (left) and image analysis to quantify the reacted fraction (right) (PhD M. Ben Haha)

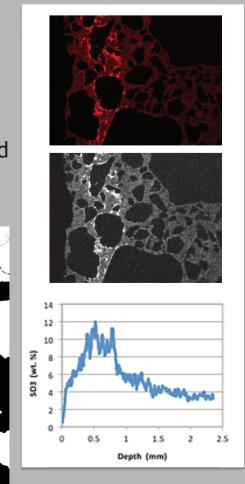


Fig. 8: Sulfate ingress profiling, accumulation of gypsum below the surface (PhD C. Yu)



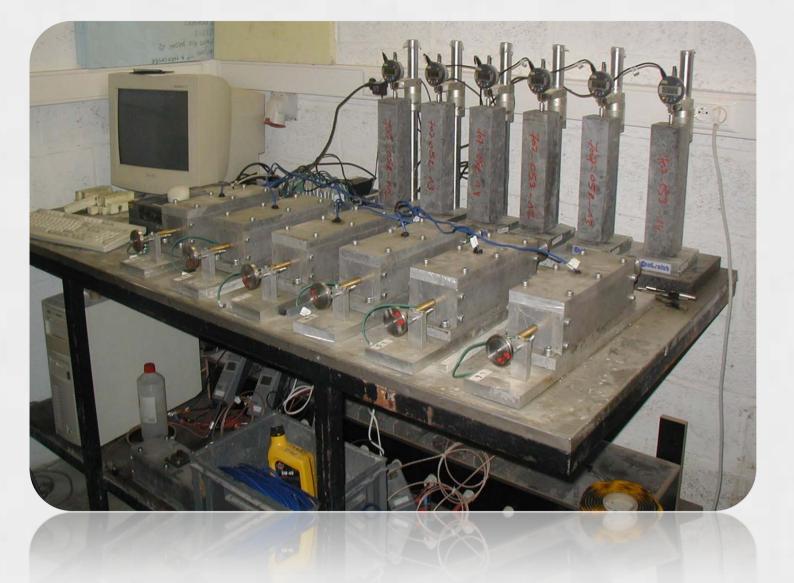


BBRI

Lab Structures: ir. B. Parmentier bp@bbri.be

Lab Concrete technology: ir. V. Dieryck vdi@bbri.be

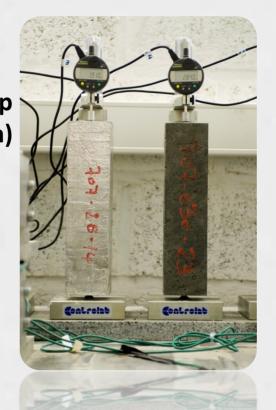
AUTOGENOUS SHRINKAGE MEASUREMENTS AT EARLY AGE (UHPC | SCC)

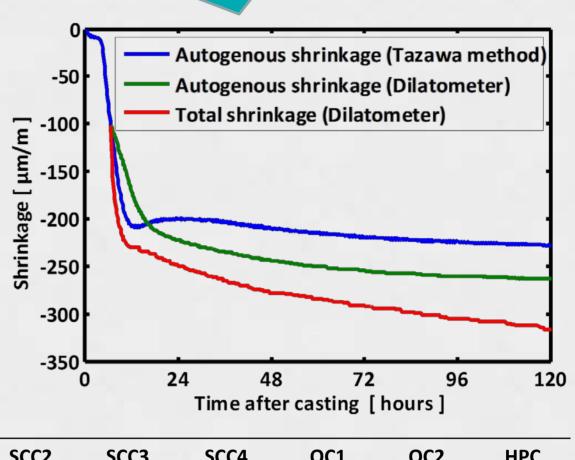


Autogenous & total shrinkage test setup (classical dilatometer method - T₀=6,6h)

Autogenous shrinkage test setup after Tazawa's work (T₀=0,5h)





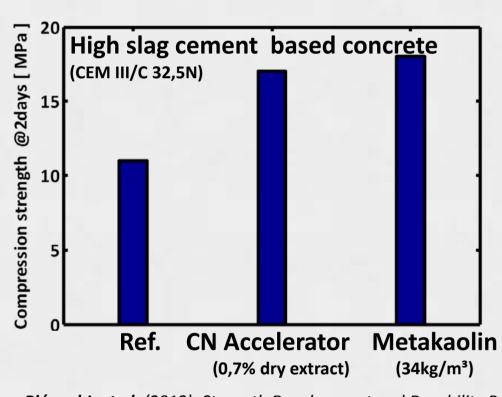


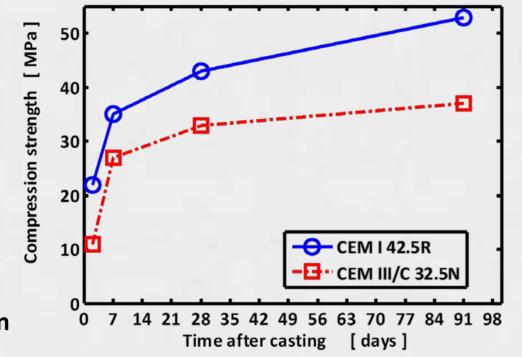
Controlate Contro	100						
Mix	SCC1	SCC2	SCC3	SCC4	OC1	OC2	HPC
W/C ratio	0.43	0.47	0.50	0.47	0.50	0.50	0.35
W/B ratio	0.26	0.28	0.30	0.35	0.50	0.50	0.33
Autogenous shrinkage	70 %	41 %	33 %	39 %	25 %	21 %	71 %
Drying shrinkage	30 %	59 %	67 %	61 %	75 %	79 %	29 %

(% total shrinkage at 56 days)

200 days

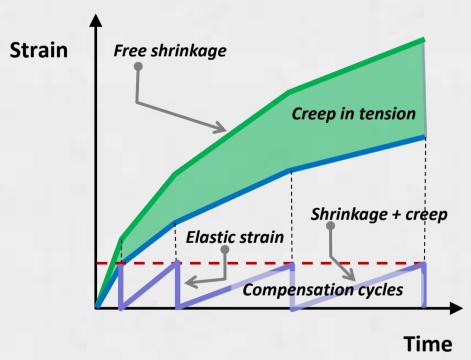
(Early age) Strenth development of **Eco-Concrete**

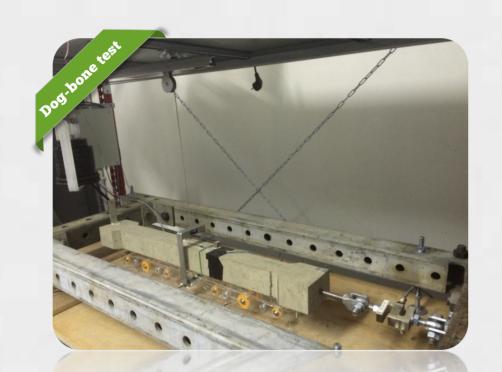




Piérard J. et al. (2012), Strength Development and Durability Properties of High Slag Cement Based Concrete fib Symposium, Stockholm.

Principle of the dog-bone test in tension (after Kovler, 1994)





CRACKING TENDENCY OF UHPC | FRC | SCC

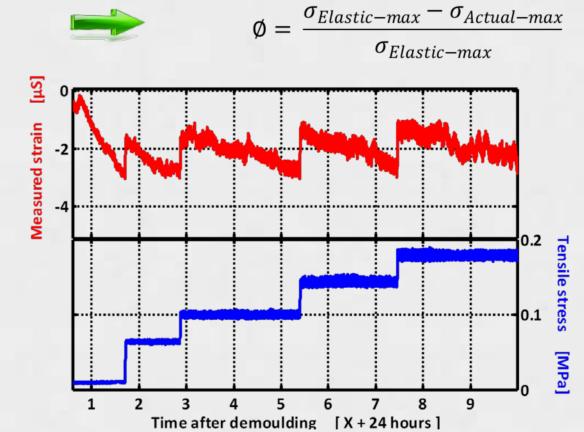
Van Itterbeeck P. et al (2010), Evaluation of the Cracking Potential of Young Self-Compacting Concrete, SCC 2010 Conference

Steel ring (t=20mm)
 Drying up & down
Strain gauges on steel innner face

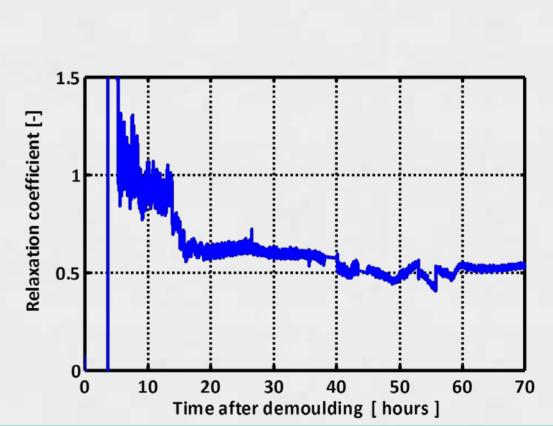
Tensile
stress

Theoretical model (elastic)

Theoretical tensile strength



 $\sigma_{Actual-max} = -\varepsilon_{st}(t).E_{S}.C_{3R}.C_{4R}$



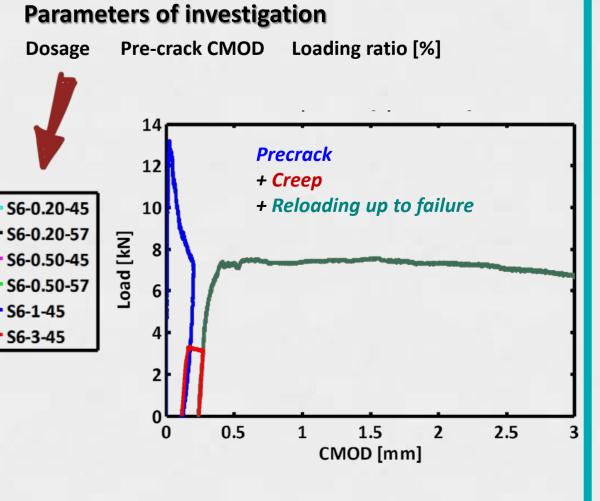
Time

Short and long term behaviour of fibre reinforced concrete (FRC) in bending

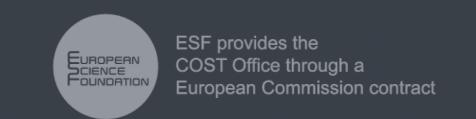




Creep of Macro Synthetic FRC (6 kg/m³) is large

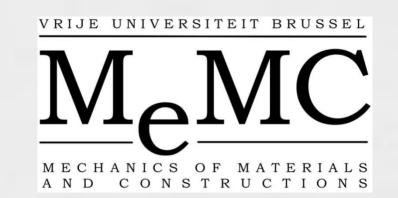


Parmentier B. et al. (2008), Evaluation of the scatter of the postpeak behaviour of fibre reinforced concrete in bending: a step towards reliability, BEFIB 2008 Conference, Chennai.





Faculty of Engineering Sciences
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Acoustic Emission and Ultrasonic Monitoring of Fresh Cementitious Materials

ABSTRACT

The final mechanical properties of cementitious media strongly depend on the early age curing. Monitoring of this process is important and conducted by non invasive techniques, Acoustic Emission (AE) and Ultrasonic (UT) monitoring.

1. INTRODUCTION

Reliable examination fresh concrete is troublesome. This study seeks a stress waves methodology that can assess parameters of the concrete performance from the time of mixing. The investigation is based on active monitoring of ultrasonic including waves, frequency dispersion and attenuation parameters, and passive monitoring by acoustic emission (AE). The kinetics of the material monitored are and correlated to the final mechanical The properties. aim methodology to make projections to the final performance based on robust engineering criteria obtained from the behavior of fresh concrete rather than assumptions and the experience of the user.

2. EQUIPMENT

For AE, resonant and broadband acoustic transducers can be attached on the standard metal mold (Fig. 1). For ultrasonics, the transducers are attached to a plastic mold and one is connected to a waveform generator to act as pulser (Fig. 2a)

Time (h) Fig. 1(a) AE monitoring setup, (b) Cumulative emissions for different water over cement ratio. The processes are completed faster for lower w/c.

4. Ultrasonic monitoring

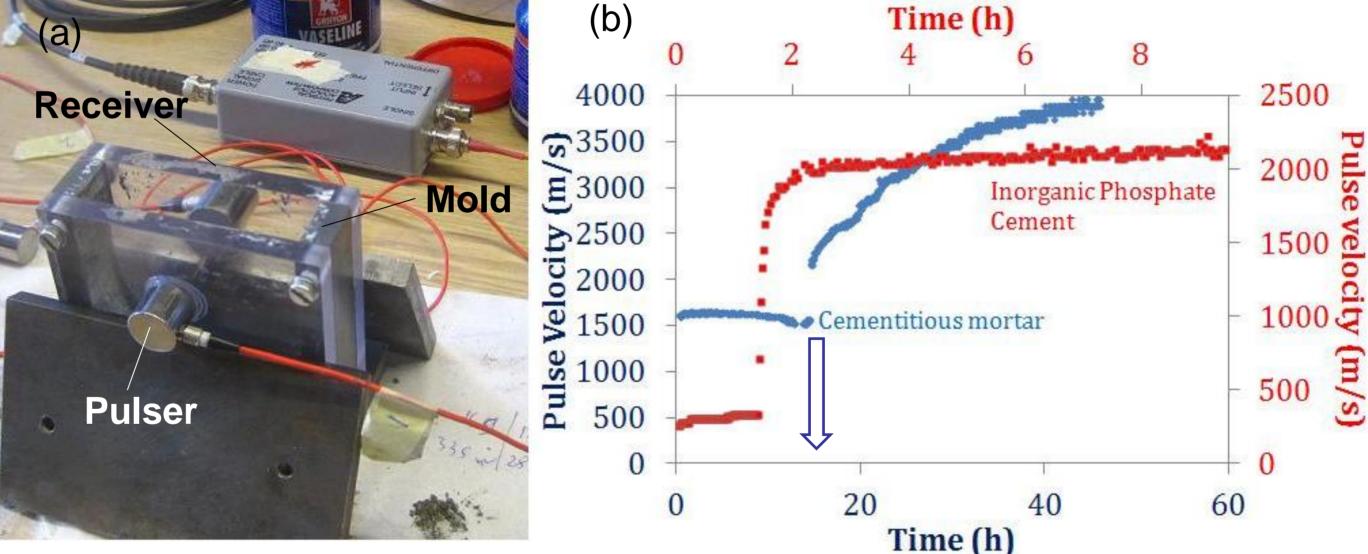


Fig. 2(a) Photo of ultrasonic setup, (b) Pulse velocity vs. hydration time for different samples

4. CONCLUSIONS

Wave velocity reveals the hydration stage, the stiffness development under different conditions, while AE activity shows the rate of processes like segregation, bubble release, water migration, early shrinkage cracking.





2. N. Robeyst, C. U. Grosse, N. De Belie, Measuring the change in ultrasonic p-wave energy transmitted in fresh mortar with additives to monitor the setting, Cement and Concrete Research 39 (2009) 868-875.

3. K. Van Den Abeele, W. Desadeleer, G. De Schutter, M. Wevers, Active and passive monitoring of the early hydration process in concrete using linear and nonlinear acoustics, Cement and Concrete Passage 39 (2009) 426–432







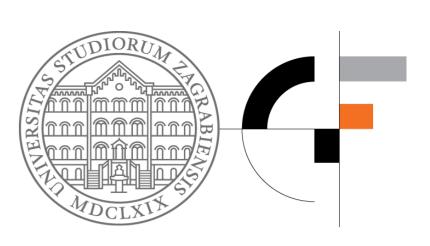




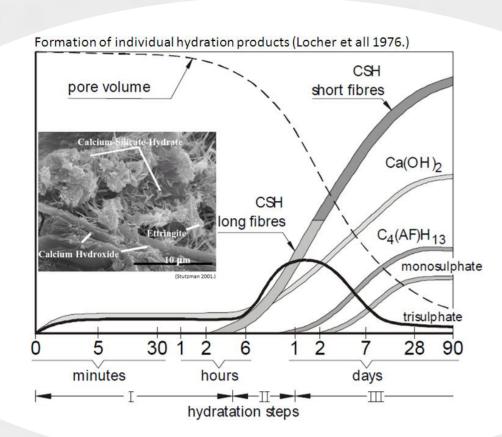


Ultrasonic monitoring of hydration induced changes in CBM's

University of Zagreb, Faculty of Civil Engineering Department of materials contact: gabrijel@grad.hr

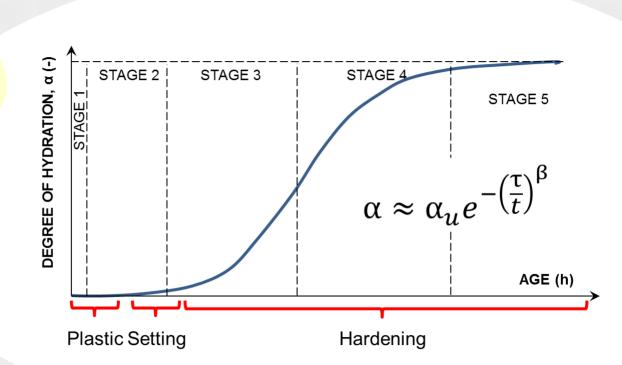


Hydration process of cement based materials



Microstructural build-up reflects at the macro scale.

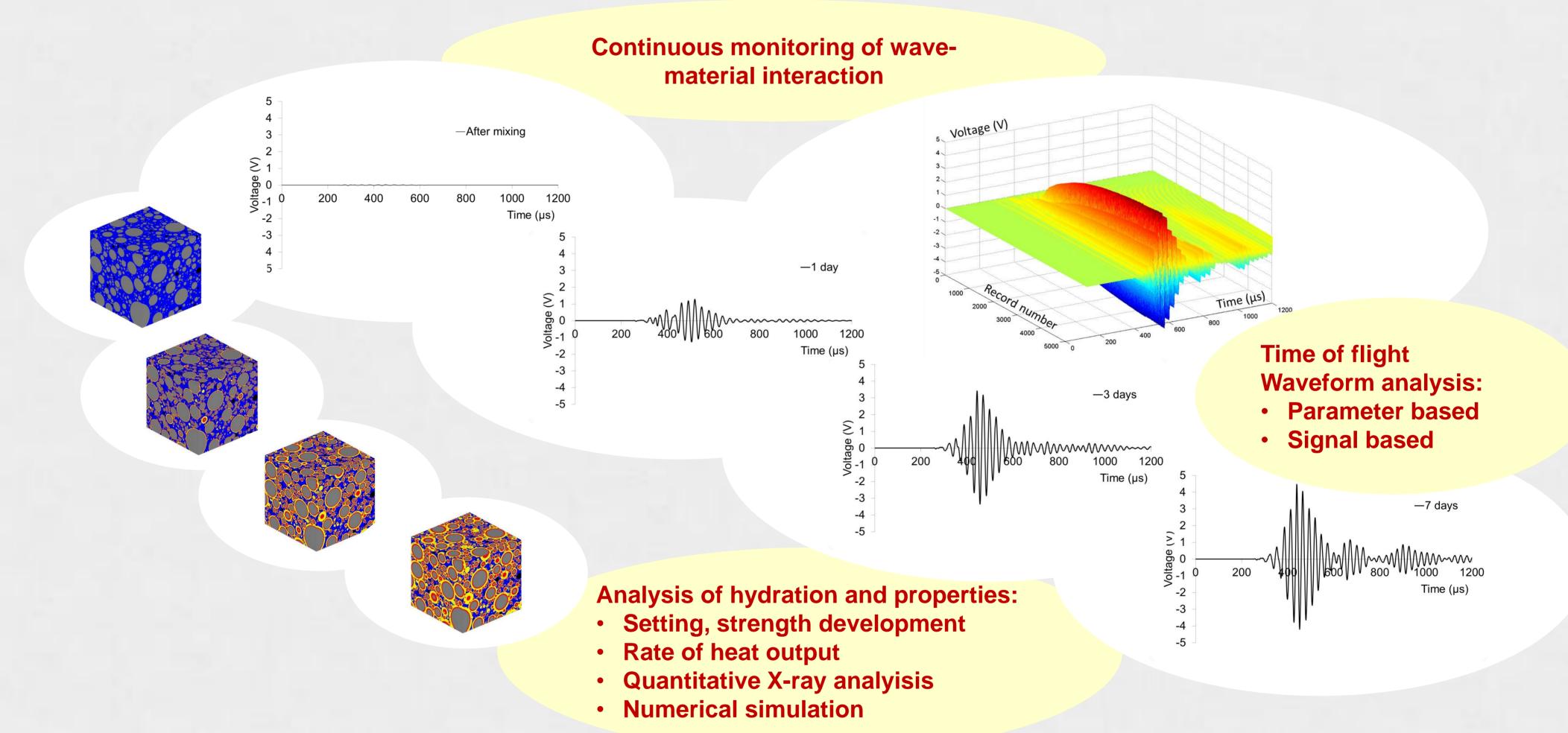
Degree of hydration is a link between microstructure and properties tested at macro scale.



Monitoring of hydration process with ultrasonic methods

Ultrasonic waves or more generally stress waves propagate through solids and interact with material.

The primary purpose of ultrasonic nondestructive evaluation is to understand the wave-material interaction and assess the sought material properties from the observed deviation in the ultrasonic response from that of an ideal, defect-free medium [Nagy, 2003]. In ultrasonic testing of early-age CBM's there is no ideal defect-free medium but instead deviations caused by changes in the material properties are studied.



Benefits and applications

Insight into structure formation mechanisms

Real-time monitoring of transition from plastic to solid state

Monitoring the rate of hydration

Evaluating influence of admixtures on setting and hardening

Prediction of strength



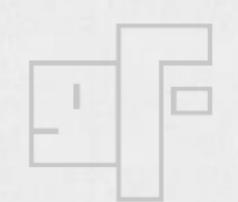




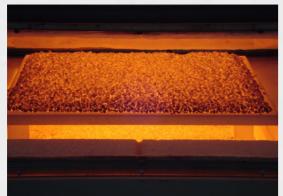




UNIVERSITY JOSIP JURAJ STROSSMAYER OF OSIJEK FACULTY OF CIVIL ENGINEERING







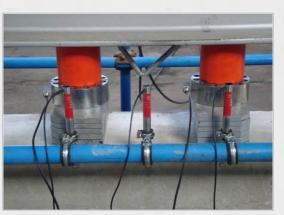






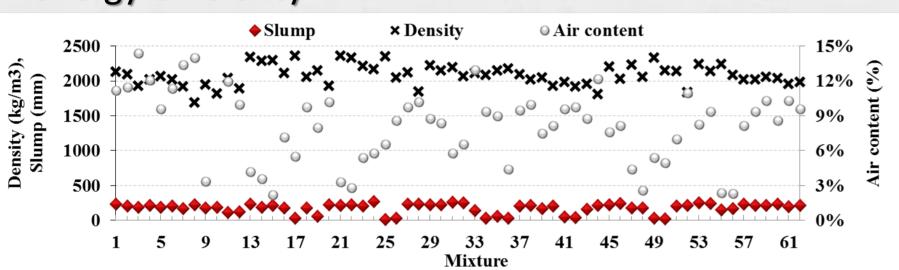




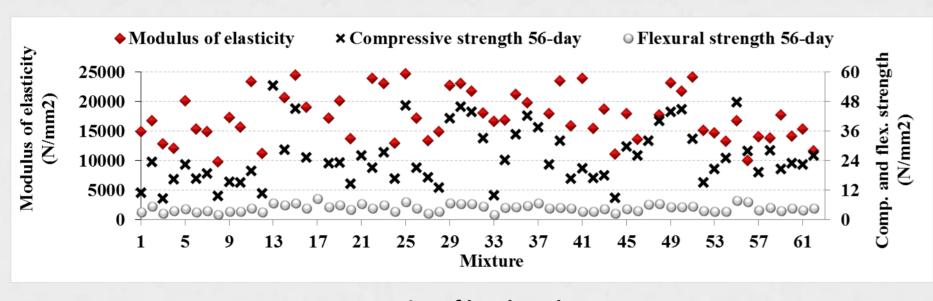


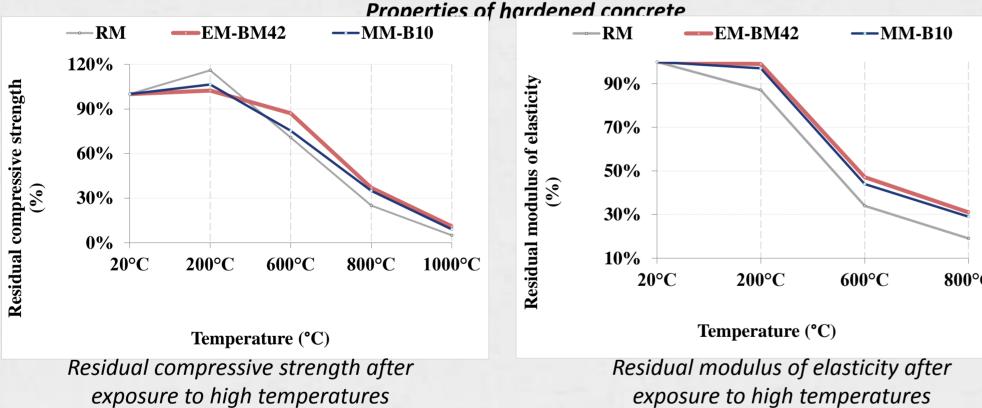
Relevant research topics

- Civil engineering materials
 - Waste materials in civil engineering
 - Alternative aggregates and binders for structural concrete
 - Alternative aggregates and binders in road pavement structure
- Testing on material characteristic level
- Testing on structural element level
- Analysis of buildings life cycle costs, service life and energy efficiency



Properties of fresh concrete





Specific topics for further study

- Environmental effect of waste materials used in civil engineering
- Pozzolanic properties of crushed bricks
- Long-term effect of waste materials in building structure
 - Heavy metals content leaching
 - Presence of volatile metals and organic compounds which can be released at high temperatures
 - Fine dust which may contain toxic and organic elements and can cause respiratory problems
 - Radioactivity
- Potential of energy savings and extension of buildings & elements service life

Specific experiences

Crushed bricks and steel slag as aggregate in ordinary concrete

Tested material properties: physical, mechanical, thermal

Crushed brick and steel slag as aggregate in fire resistant concrete

Tested basic engineering properties of fire resistant concrete

Aplication of crushed bricks in precast concrete floor elements

Alkali activated binders - geopolymers

Steel slag as aggregate in hydraulically bound mixes

 Tested basic engineering properties of cement stabilized pavement layer with different aggregates

Fly ash as binder in hydraulically bound mixes

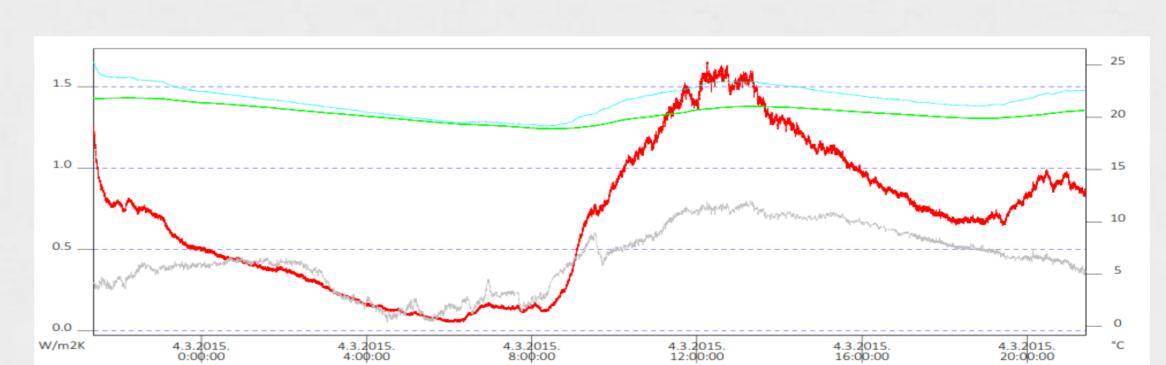
 Tested basic engineering properties of cement stabilized pavement layer with different binders

Service life predictions of existing and new buildings and elements

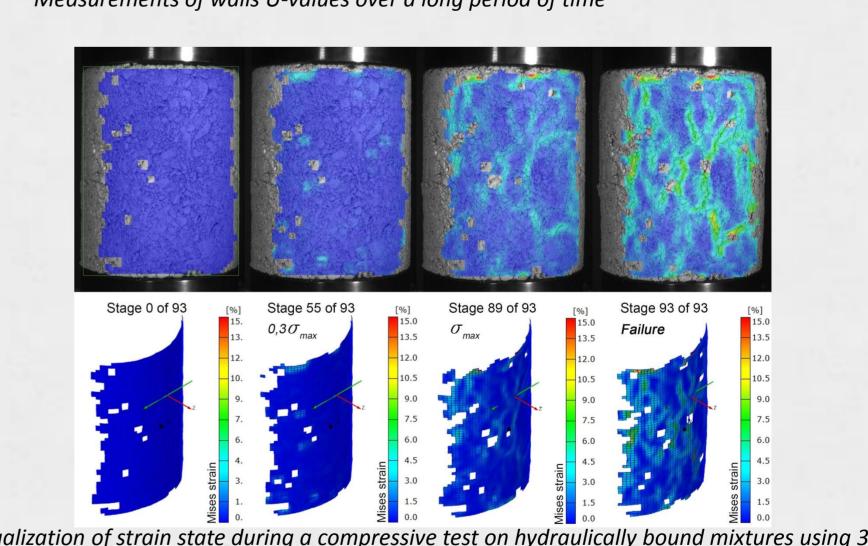
Examination of types of building service life

Testing airtightness & energy efficiency of buildings

 Determination of energy savings over the service life of the buildings



Measurements of walls U-values over a long period of time



Visualization of strain state during a compressive test on hydraulically bound mixtures using 3D digital image correlation technique

TU1404 MEMBERS:

Ph.D. Ivanka Netinger Grubeša, nivanka@gfos.hr Ph.D. Ivana Barišić, <u>ivana@gfos.hr</u> Ph.D. Ivana Miličević, <u>ivana.milicevic@gfos.hr</u>









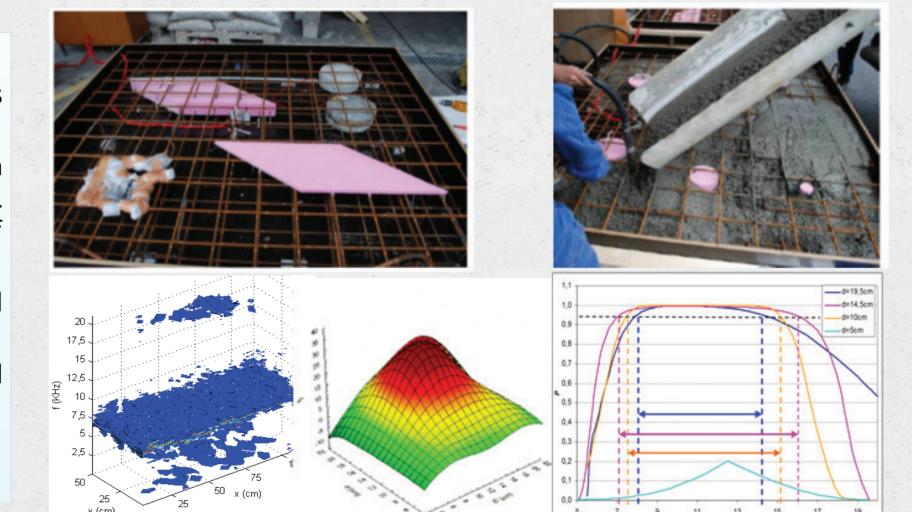
Ph.D. Hrvoje Krstić, hrvojek@gfos.hr

INSTITUT IGH - Laboratory for materials - Laboratory for concrete - Zagreb

MAIN RESEARCH PROJECTS

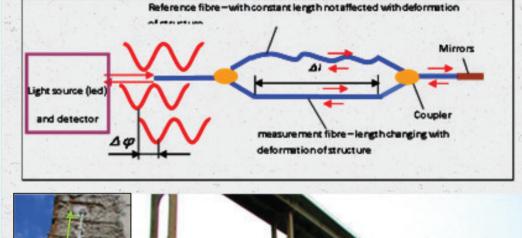
Research of Impact - Echo Method feasibility

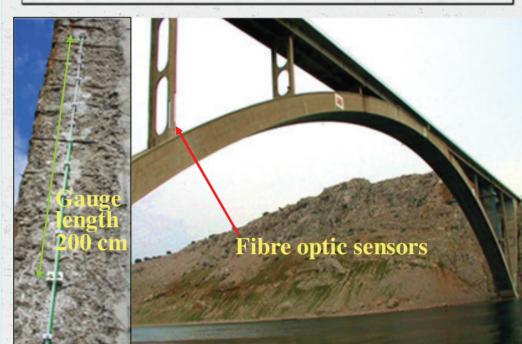
- PhD project resulted in dissertation
- Impact-echo is an acoustic method, which utilizes reflections of transient elastic waves from damaged areas of a structural element to assess its condition.
- Objectives of research are more accurate determination of detection limits of damages in reinforced concrete structures with the use of IE method and establishment of statistical model for probability of detection prediction in respect to type, size and depth of damages.
- For the experimental research, an experimental reinforced concrete field with embedded damages of different sizes placed at different depths was designed and manufactured.
- Measured responses are processed by standard Fast Fourier Transform (FFT) method and by alternative spectral analysis methods
- From test results, based on intensity of noise and on intensity of responses from damages, a probability of detection (POD) model was created.

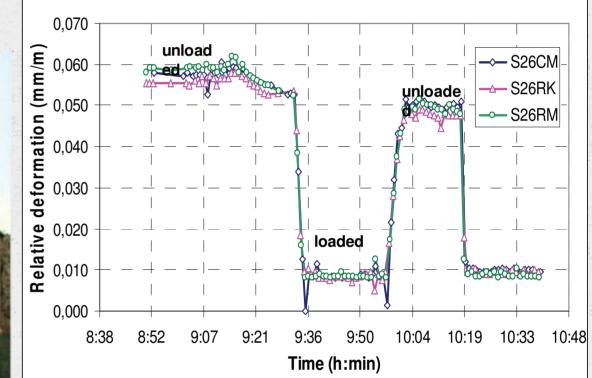


Application of fibre optic sensors for deformation measuraments on Krk bridge coloumns

- Institute IGH project
- First application of fiber optics in the field of Civil Engineering in Croatia
- During the repair work design of Krk Bridge Columns some important questions and open issues appeared:
- the stress increase rate in the rest of the concrete after hydrodemolition of the concrete cover,
- the rate of elastic deformation and plastic creeping caused by disburdening of column,
- the rate of influence of the new concrete shrinkage on additional longitudinal loading
- how the new layers (of repairing concrete) affect loading capacity of the repaired columns - when and in which rate will new concrete participate in useful freight bearing.
- For measurements, long gauge fibre optic sensors (L=2m, Resolution=0,001 mm) are selected to insure measurement of average deformation avoiding influence of local deformation changes.
- Test results are used for statical analysis of concrete structure

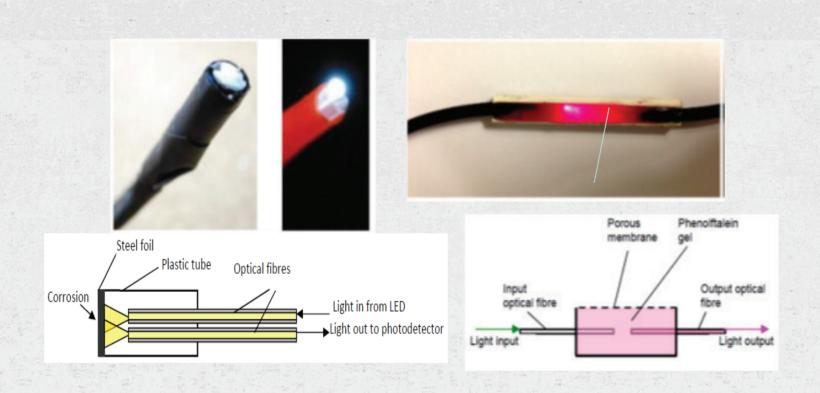




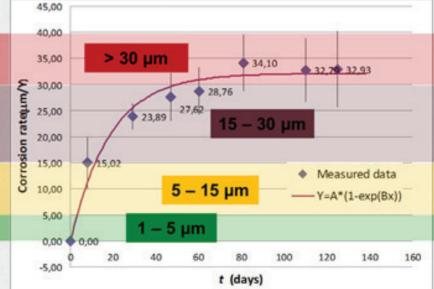


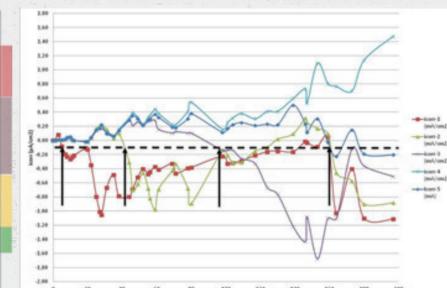
Corrosion monitoring system developement

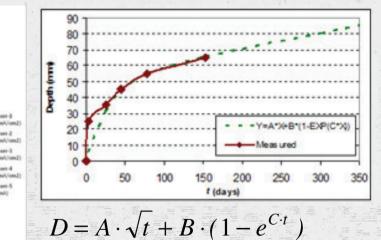
- FP7 European Comission project "TRIMM" 2011-2014
- Project task "Corrosion monitoring"
- The common goal in all tasks in WP3 is to overcome the gaps and barriers in European deployment of innovative bridge monitoring methods to increase availability, structural safety and cost-efficiency.
- To ensure confident corrosion indication, integration of several corrosion monitoring techniques is included into one advanced corrosion monitoring system.
- Self-constructed sensors based on fiber optical and electrochemical methods was developed.
- Sensors are tested in the laboratory and at the field
- Correlations Between different measurement parameters are established (half cell potential, macrocell current, electrical resistivity of concrete, chlorides concentration in concrete...)
- Developed corrosion monitoring system was implemented on real RC bridges
- Corroaion Criteria for assesment of damages was established
- Model for corrosion prediction from measurement data was proposed

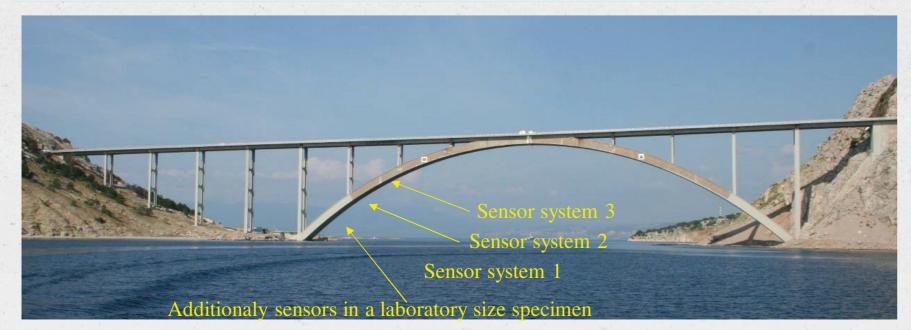




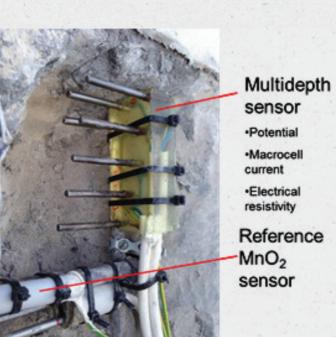


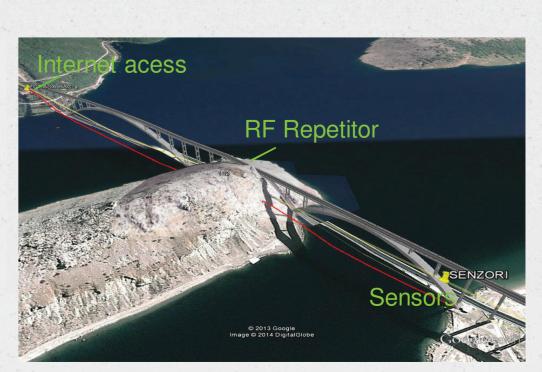












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CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF CIVIL ENGINEERING, EXPERIMENTAL CENTRE Experimental investigation of the ultra-high-performance

fibre-reinforced cementitious composites corresponding author R.Sovják (sovjak@fsv.cvut.cz)

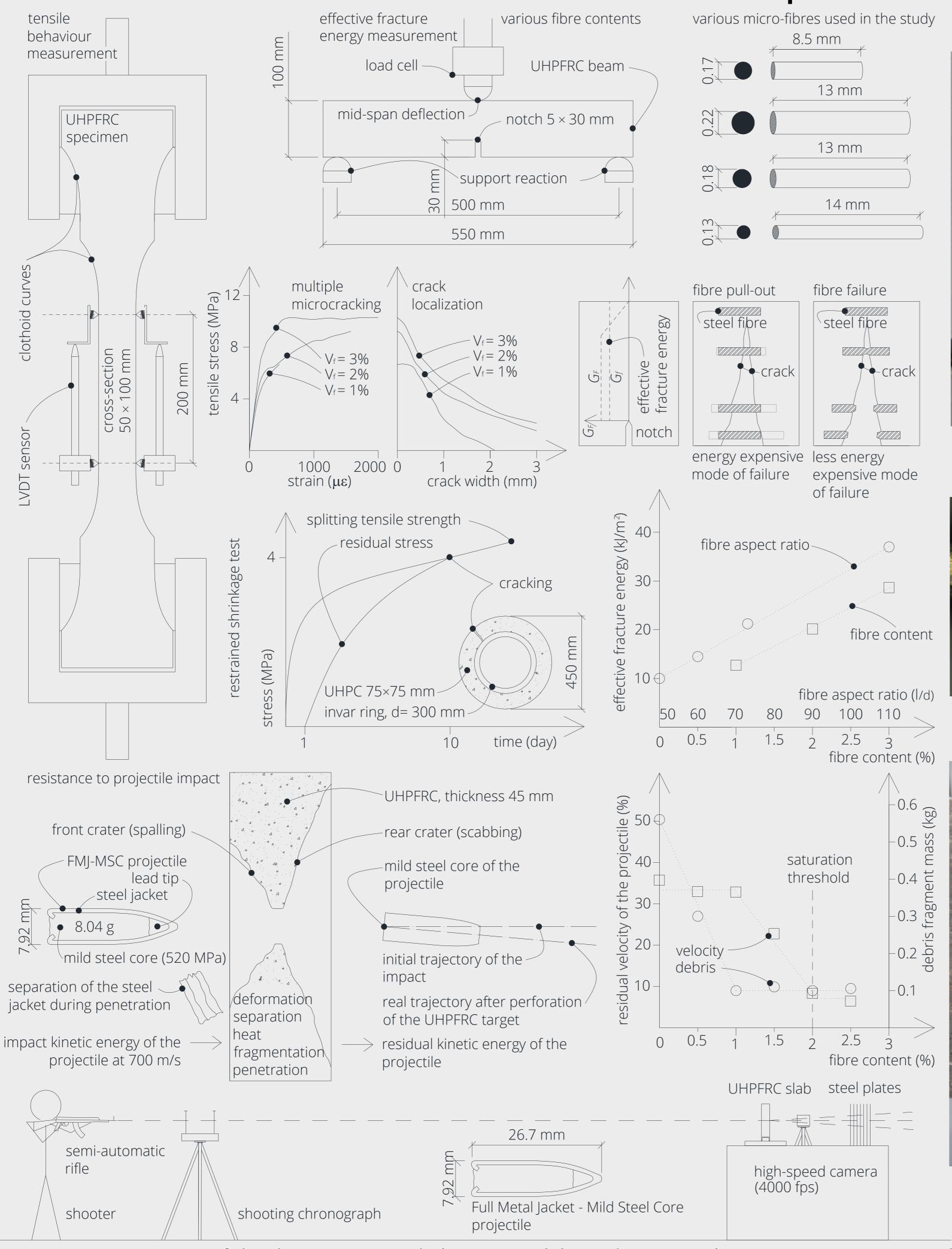




Fig.1 Micro-fibres used in the UHPFRC mixture (13×0.18 mm)

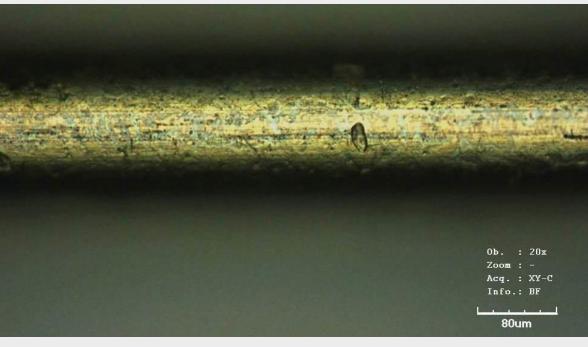
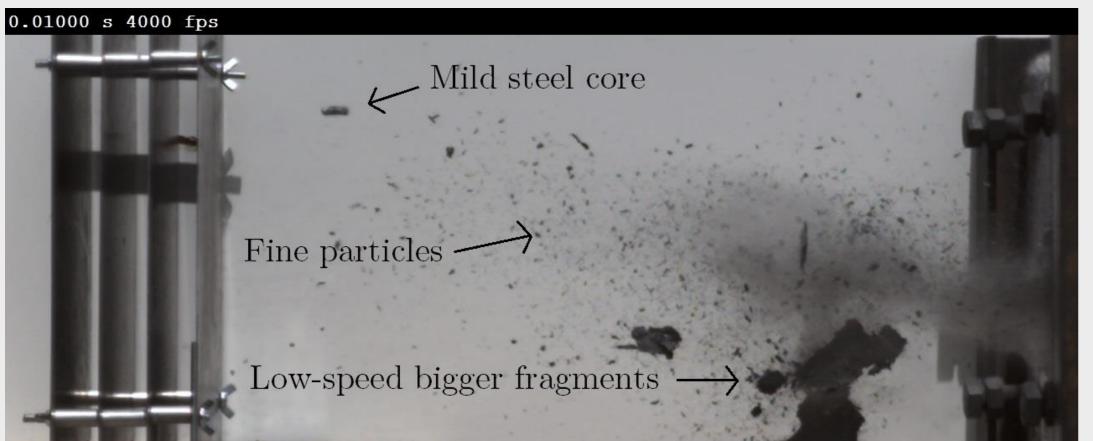


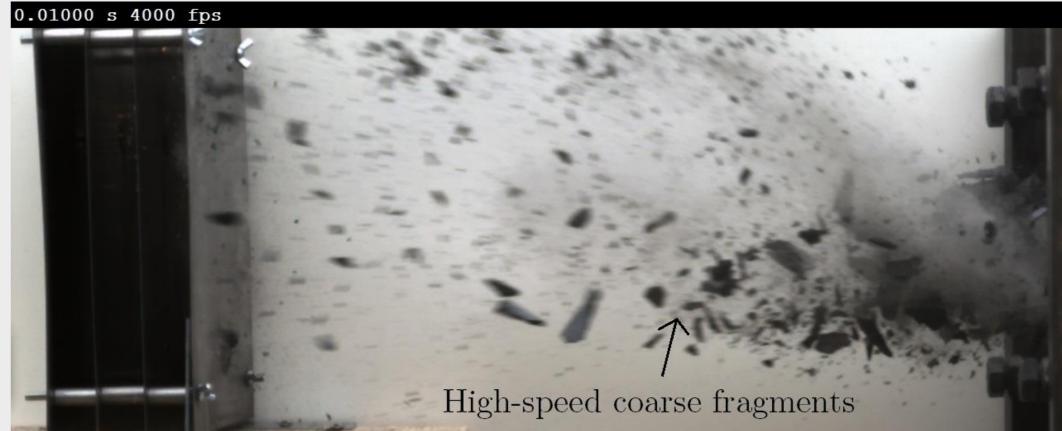
Fig.2 Detail of the smooth steel microfibre with tensile strength of 2.8 GPa



Fig.3 Fracture energy of the UHPFRC measured on the notched specimen

Fig.4 Fragmentation of the thin UHPFRC and plain UHPC slabs under projectile impact using in-service bullet with impact velocity of 700 m/s













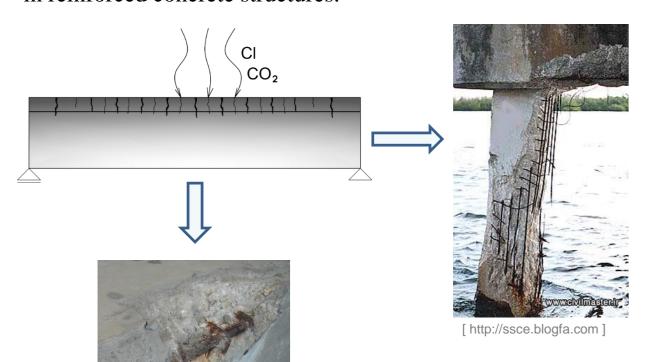
WG2: Model of carbonation and chloride ingress for cracked concrete structures

Karolina Hájková, Vít Šmilauer

Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics

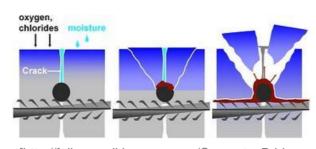
Introduction

Maintenance cost in construction industry is estimated as 30-40% of the total budget. Carbonation and chloride ingress are the most relevant damage mechanisms for steel corrosion in reinforced concrete structures.



Chloride ingress

Reinforcement corrosion when chloride starts concentration exceeds about 0.6% of the binder mass.

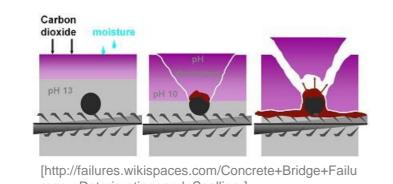


[http://failures.wikispaces.com/Concrete+Bridgeting) e+Failures+-+Deterioration+and+Spalling

Carbonation

A diffusion-driven process is accelerated by the presence of cracks. Decrease of pH under cca $9 \rightarrow$ depassivation of reinforcement -> corrosion of reinforcement.

[http://en.wikipedia.org/wiki/Concrete_degradation]



Objectives

- 1. Macroscopic modelling of CBM behaviour during life cycle.
- 2. Formulation of thermo-hydro-mechanical model of concrete at a structural level. Multi scale coupling with model of cement hydration.
- 3. Extension of transport models for the influence of cracks.

Preliminary results

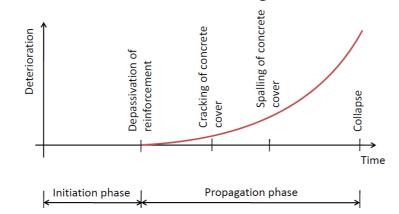
Cracks have strong impact on transport acceleration in concrete. The table below shows induction time for two concretes with cover thickness 30 mm and relative humidity 0.6.

Crack width (mm)	Concrete C=400 kg/m3	Concrete C=200 kg/m3
	P(fly ash)= $50 \text{ kg/m}3$	P=0 kg/m3
	w/b=0.45	w/b=0.45
0	246	157
0.1	69.7	44.5
0.2	49.2	31.4
0.3	39.1	24.9

The table shows that cracks 0.3 mm decrease about 6x induction time for carbonation.

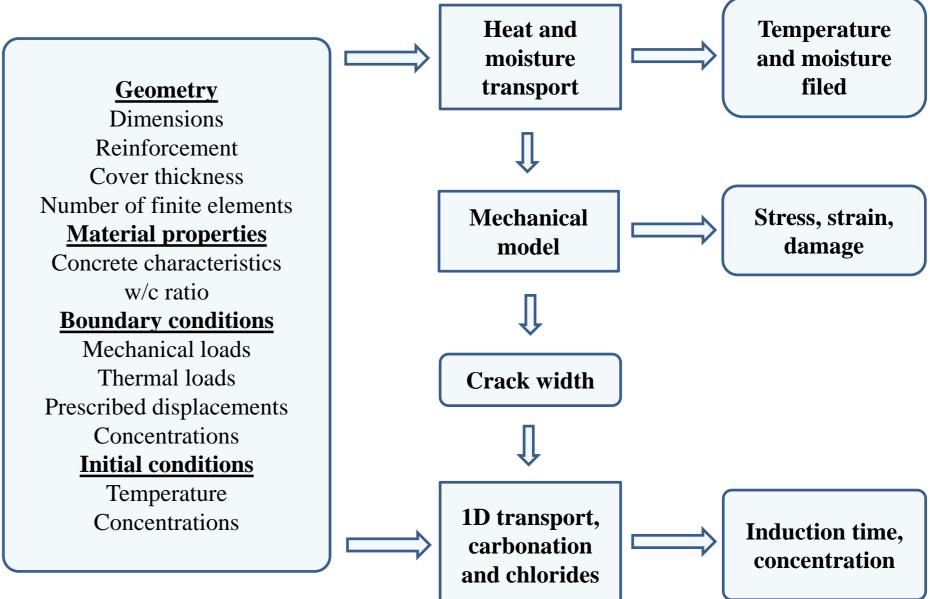
The table below shows induction time for submerged concrete in sea water with cover thickness 100 mm. Cracks 0.3 mm decrease about 9x induction time for chloride ingress.

Crack width (mm)	Concrete
	w/b=0.55
0	74.58
0.1	36.02
0.2	15.70
0.3	7.76

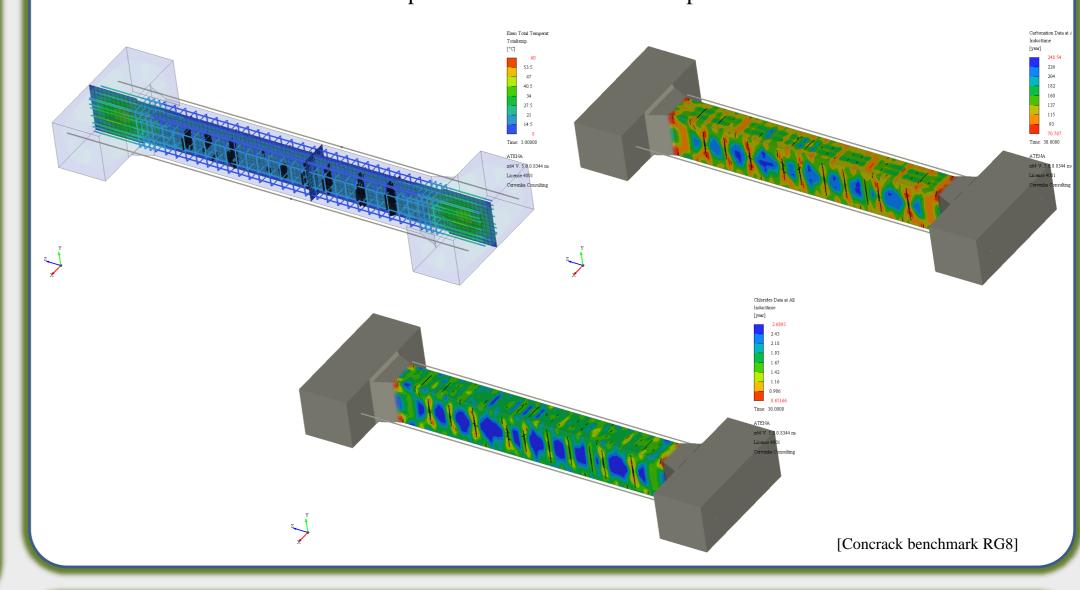


Thermo-hydro-mechanical model

A new engineering model for carbonation and chloride ingress combines recent results from concretes made from blended cements. The model includes macroscopic cracks which accelerate transport mechanisms. Given the cover thickness of concrete, the model predicts the end of initiation phase and the beginning of the propagation phase. Different boundary conditions reflecting various exposition classes can be set up. The model allows simulating accelerated carbonation tests or to study the effect of early-age cracking due to excessive drying or excessive mechanical load. The model allows the coupling effect between crack growth and carbonation progress.



Input parameters of the model are geometry, material properties, boundary conditions and initial conditions of concrete structure. In the first step, temperature and moisture filed are obtained using heat and moisture transport model. The consecutive mechanical model calculates stress, strain, damage and crack width of concrete structure. Crack width is the input for the last stage where 1D semi-analytical transport model calculates carbonation front and chloride concentration. The presented model has been implemented in ATENA software.



1D model for carbonation and chloride ingress with cracks

Carbonation depth xc

• Macroscopically uncracked concrete (Padadakis & Tsimas, 2002)

$$x_c = \sqrt{\frac{2D_{e,CO_2}CO_2}{0.218(C+kP)}} \sqrt{t} = A_1 \sqrt{t}$$

$$C \text{ is OPC in kg/m}^3$$

$$P \text{ is SCM in kg/m}^3$$

$$k \text{ is efficiency factor}$$

• Crack width w accelerates carbonation (Kwon & Na, 2011) $x_c(t) = (2.816\sqrt{w} + 1)A_1\sqrt{t}$

• Empirical effective diffusivity (Papadakis & Tsimas, 2002)

$$De, CO_2 = 6.1 * 10^{-6} \left(\frac{\frac{[W - 0.267(C + kP)]}{1000}}{\frac{C + kP}{\rho_C} + \frac{W}{\rho_W}} \right)^3 * (1 - RH)^{2.2}$$

• Crack generally evolves over time, an incremental form

$$2 = 6.1 * 10^{-6} \left(\frac{\frac{[W - 0.267(C + RP)]}{1000}}{\frac{C + kP}{\rho_c} + \frac{W}{\rho_w}} \right) * (1 - RH)^{2.2}$$

$$1 = 6.1 * 10^{-6} \left(\frac{\frac{[W - 0.267(C + RP)]}{1000}}{\frac{C + kP}{\rho_c} + \frac{W}{\rho_w}} \right) * (1 - RH)^{2.2}$$

$$1 = \frac{(2.816\sqrt{W_{i+1}} + 1)A_1}{2\sqrt{t_{i+0.5}}} \Delta t + \frac{2.816A_1\sqrt{t_{i+0.5}}}{2\sqrt{W_{i+0.5}}} \Delta w$$

$$2 = 6.1 * 10^{-6} \left(\frac{\frac{[W - 0.267(C + RP)]}{1000}}{\frac{C + kP}{\rho_w} + \frac{W}{\rho_w}} \right) * (1 - RH)^{2.2}$$

$$2 = 6.1 * 10^{-6} \left(\frac{\frac{[W - 0.267(C + RP)]}{1000}}{\frac{C + kP}{\rho_w} + \frac{W}{\rho_w}} \right) * (1 - RH)^{2.2}$$

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$$2 = 6.1 * 10^{-6} \left(\frac{\frac{[W - 0.267(C + RP)]}{1000}}{\frac{[W - 0.267(C + RP)]}{1000}} \right) * (1 - RH)^{2.2}$$

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$$2 = 6.1 * 10^{-6} \left(\frac{\frac{[W - 0.267(C + RP)]}{1000}} \right) * (1 - RH)^{2$$

Chloride ingress

• 1D transient ingress

$$C(x,t) = C_s \left[1 - erf\left(\frac{x}{2\sqrt{D_m(t)f(w)t}}\right) \right] \quad \begin{array}{l} C_s \text{ is the chloride surface in kg/m}^3 \\ D_m \text{ is the mean diffusion coefficient in } m^2/s \end{array}$$

Acceleration by cracking (Kwon, Na, Park, Jung, 2009) $f(w) = 31.61w^2 + 4.73w + 1$

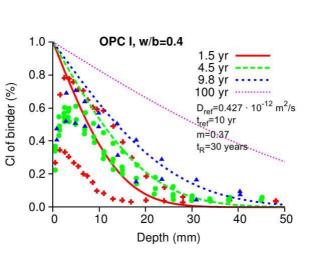
• Diffusion coefficient- time depended

$$D(t) = D_{ref} \left(\frac{t_{ref}}{t}\right)^m$$

• Averaging yields the mean coefficient

$$D_m(t) = \frac{1}{t} \int_0^t D_{ref} \left(\frac{t_{ref}}{\tau}\right)^m d\tau = \frac{D_{ref}}{1-m} \left(\frac{t_{ref}}{t}\right)^m, t < t_R$$

$$D_m(t) = D_{ref} \left[1 + \frac{t_R}{t} \left(\frac{m}{1-m}\right)\right] \left(\frac{t_{ref}}{t_R}\right)^m, t \ge t_R$$



Conclusions

Preliminary results show strong influence of cracks to transport properties. For traditional CBM, cracks 0.3 mm decrease induction time about 6x for carbonation and 9x for chloride ingress. Preventing macrocracks and designing proper concrete mixture are prerequisities for durable concrete.

We gratefully acknowledge financial support from SGS15/029/OHK1/1T/11 granted by Czech Technical University in Prague.

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material design for hostile marine environments

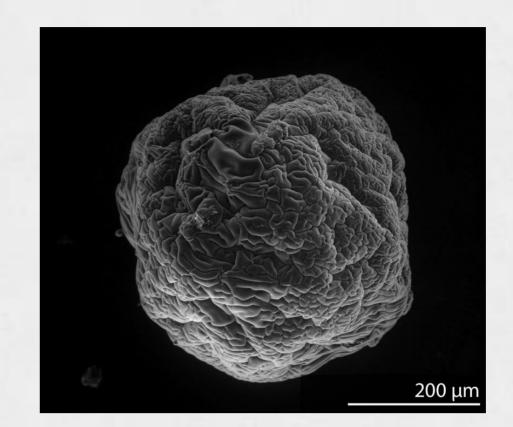
luis pedro esteves, lars damkilde

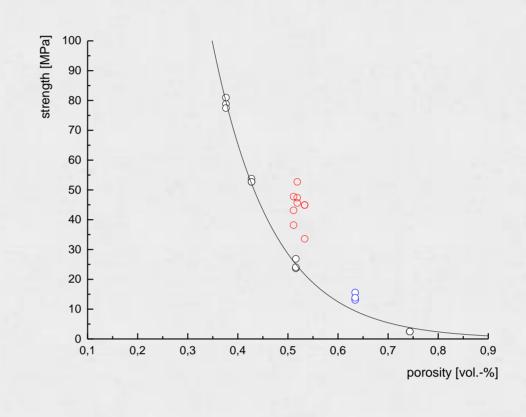
focus on material design and modeling of offshore concrete structures.

with a history of great achievements, we aim to develop the baseline holistic experimental modeling of advanced ultra-high performance cement-based materials.

and by this contribute to the next generation of model laws for ultra-high performance concrete materials and structures.



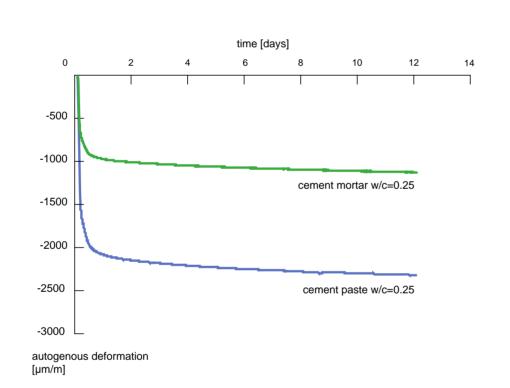




shrinkage and cracking

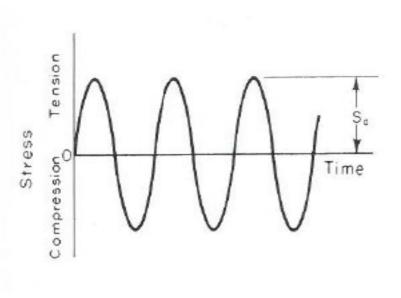


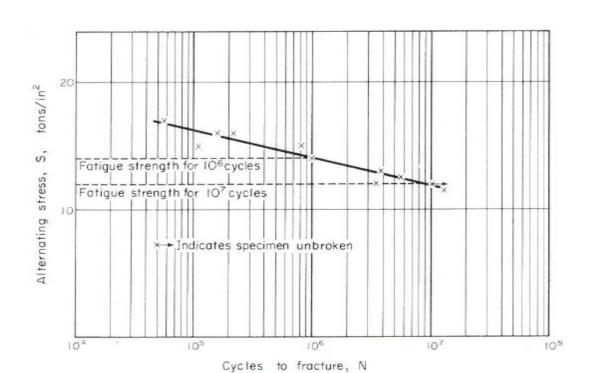
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fatigue





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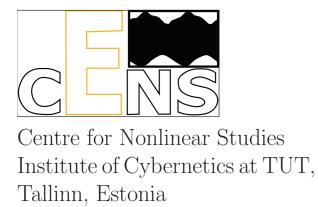
Grouted Connections with Shear Keys: Numerical modelling with ABAQUS. / Pedersen, Ronnie; Jørgensen, M. B.; Damkilde, Lars; Clausen, H. B.; Andersen, K. In Proceedings of the 25th Nordic Seminar on Computational Mechanics. ed. / K. Persson; J. Revstedt; G. Sandberg; M. Wallin. Lund: Lund University, 2012.



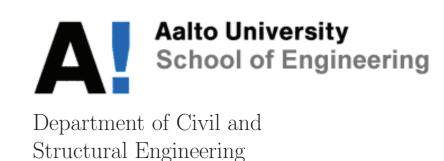








Steel Fibre Reinforced Concrete: from science to practice



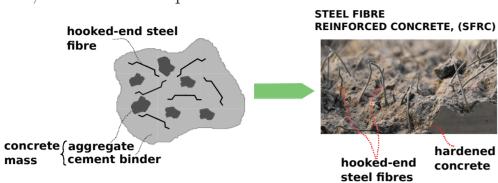


Marika Eik & Heiko Herrmann & Jari Puttonen {marika.eik, jari.puttonen}@aalto.fi, hh@cens.ioc.ee



Introduction

Formed by mixing of fresh concrete with steel fibres, which improves concrete-matrix mechanical properties leading, however, to an anisotropic material behaviour

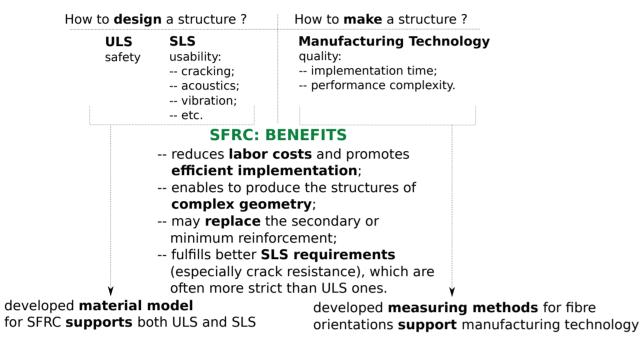


INTENTION & MOTIVATION FOR RESEARCH:

strengthen the reliability of using SFRC in load-bearing structures: tunnels, bridges, buildings

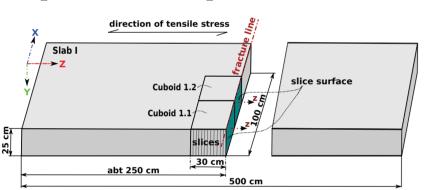
Why SFRC?

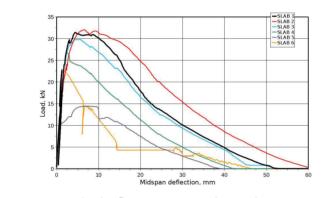
Realization of a construction project:



Developed measuring methods to support SFRC casting practice (more detailed in [3, 4])

Experimental specimens



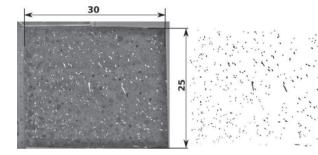


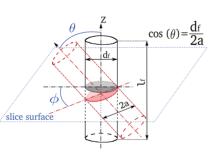
6 full-size floor slabs, site-specific casting

Load-deflection in bending

Slicing with DC-conductivity joined with image analysis

Slicing with image analysis



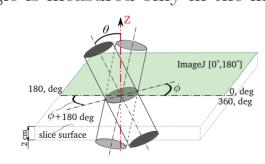


Filtered and binary images of a slice

Inclination θ and in-plane ϕ angles by shape of fitted ellipse

Ambiguity in the direction of a fibre:

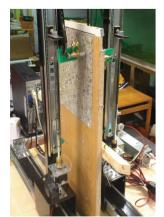
in-plane ϕ angle is measured only in the interval $[0^{\circ}, 180^{\circ}]$



DC-conductivity testing combined with image analysis:

ability to measure the in-plane angle ϕ in the interval $[0^{\circ}, 360^{\circ}]$, which eliminates the ambiguity in the direction of a fibre

- utilises the coordinates of cut fibres defined in image analysis;
- is based on physical property: measuring of electrical conductivity between the cut ends of steel fibres.





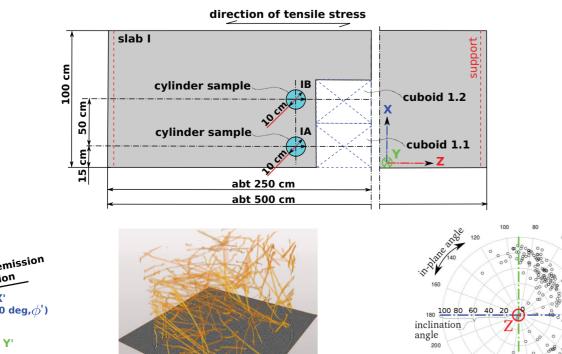


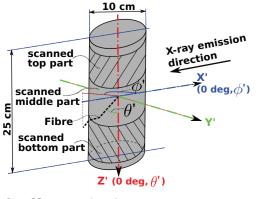
Prototype of a robot

Scanning of a slice surface

A probe

X-ray micro-tomography





cylinders

Sufficiently large rotating Skeletonised (centre lines) representation of fibres

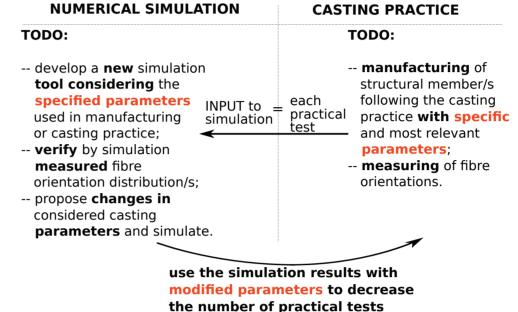
Scatter plot of fibre

orientations

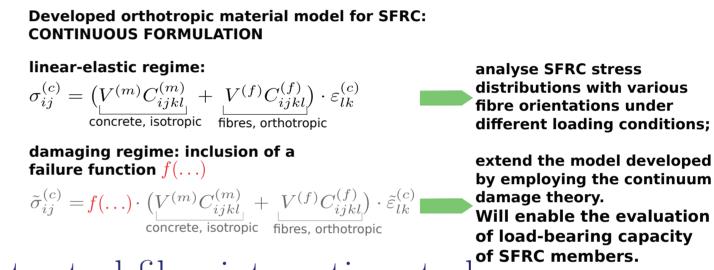
Advantages of measuring methods developed or tested

- Combination of DC-conductivity with image analysis:
- provides fast scanning time;
- prevents the ambiguity in the in-plane angle;
- does not require expensive technical solutions.
- µCT scanning:
 - provides precision of measurements superior to other methods;
- provides CT-systems requiring limited knowledge of X-ray methods.

Develop SFRC casting process to optimise fibre orientation



Implementation of the developed SFRC material model in Finite Element Method simulations (more detailed in [1, 2])



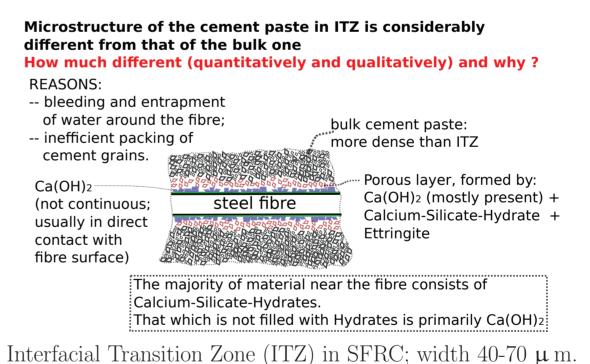
Concrete-steel fibre interaction study

Adhesion:

- caused by intermolecular interactions in the surface layer of contacting bodies. Loosing of adhesion \Rightarrow gradual debonding \Rightarrow concrete cracking \Rightarrow crack opening (important for crack width control!)

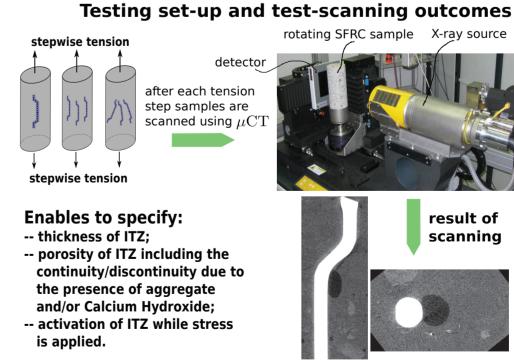
- influenced by the special microstructure of the cement paste at vicinity of a fibre:

Interfacial Transition Zone (ITZ)



Inhomogeneous microstructure of $ITZ \Rightarrow complex mode$ of cracking and debonding

Experimental investigation of adhesion by X-ray micro-computed tomography

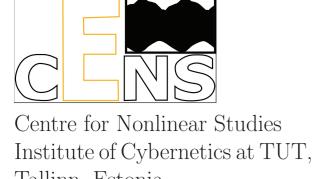


Expected outcomes of the study

- increase of concrete-matrix first cracking stress;
- better control over the initiation and propagation of cracks assuming the favourable debonding mode at or close to fibre-matrix interface.

References

- 1. M. Eik, J. Puttonen, H. Herrmann; Composite Structures, 121, 324-336, http://dx.doi.org/10.1016/j.compstruct.2014.11.018, March 2015
- 2. H. Herrmann, M. Eik, V. Berg, J. Puttonen; *Meccanica*, 49, 8, 1985-2000, http://dx.doi.org/10.1007/s11012-014-0001-3, July 2014
- 3. M. Eik, K. Lõhmus, M. Tigasson, M. Listak, J. Puttonen, H. Herrmann; Journal of Materials Science, 48, 10, 3745-3759, http://dx.doi.org/10.1007/s10853-013-7174-3, May 2013
- 4. J.-P. Suuronen, A. Kallonen, M. Eik, J. Puttonen, R. Serimaa, H. Herrmann; Journal of Materials Science, 48, 3, 1358-1367, http://dx.doi.org/10.1007/s10853-012-6882-4, February 2013



Orientation of steel fibres in concrete: measuring and modelling





Structural Engineering



Marika Eik & Jari Puttonen & Heiko Herrmann {marika.eik, jari.puttonen}@aalto.fi, hh@cens.ioc.ee

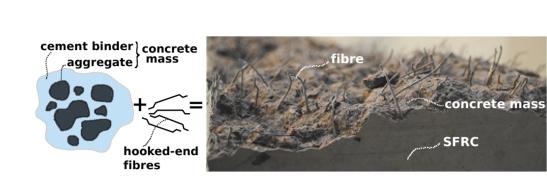
Introduction

Composite: Steel Fibre Reinforced Concrete (SFRC)

Formed by mixing of fresh concrete with short steel fibres

Adding fibres to concrete matrix improves mechanical properties leading, however, to an anisotropic

behaviour



State of concrete matrix:

- hardened
- Type of fibres:
- straight steel fibres with hooked ends
- aspect ratio: $\frac{l_f}{d_f} = \frac{50}{1}$
- amount: $80 \ kg/m^3$

MOTIVATION FOR RESEARCH:

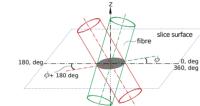
management of short steel fibre orientation needed for the specification of SFRC bearing capacity is still more or less an open question for engineering community

The main goals of the research

- 1. Development and implementation of methods for measuring fibre orientations:
 - Slicing based on the combination of DC-conductivity testing with photometry
 - slicing with photometry
 - slicing with DC-conductivity joined with photometry
 - X-ray micro-computed tomography (μCT)
- 2. Development of an orthotropic material model for SFRC

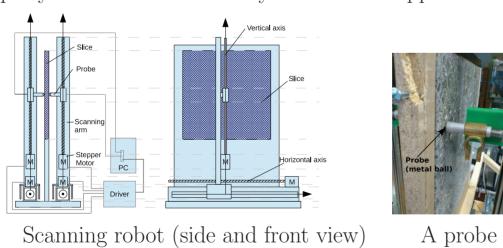
Slicing with photometry Load-deflection diagram of slabs tested by Full-size floor-slab three point bending test Measuring the inclination θ and Filtered (left) and binary (right) in-plane ϕ angles using the geometry images of a slice Sample cuboid with slices of cut fibres **Shortcoming:** in-plane angle ϕ is measured only in the interval $[0^{\circ}, 180^{\circ}]$ causing the ambiguity

in the direction of a fibre.



Slicing with DC-conductivity joined with photometry

Extension of slicing with photometry \Rightarrow uses the coordinates of cut fibres received in photometry Based on physical property: electrical conductivity between the opposite endpoints of cut fibres



Advantages:

- fast scanning time

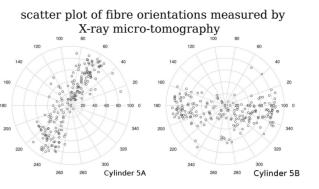
– prevents the ambiguity in the in-plane angle

- does not require expensive technical solutions

X-ray micro-computed tomography (µCT) Scatter plot of fibre orientations Sufficiently large cylinder 3D voxel representation and analysis of skeleton-objects samples precision of measurements is unparalleled with other methods Advantages: - availability of CT-systems, which require limited knowledge of X-ray methods

Assumptions for constitutive mappings of SFRC

anisotropy



Anisotropy can be modelled by an orthotropic material model

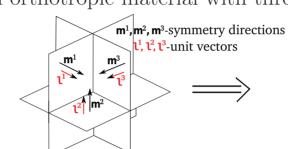
physically linear-elastic

Is justified as tension stresses in concrete matrix should be kept low to keep concrete uncracked

Hook's law (stress, S_{ij} , strain, E_{lk} , relation) as a starting point: $S_{ij} = C_{ijkl} E_{lk},$ where C_{ijkl} is the 4^{th} order elasticity tensor.

Modelling of isotropic concrete matrix and anisotropic influence of short fibres

– an orthotropic material with three principle material directions $\{\mathbf{m}^{(i)}\}_{i=1.2.3}$

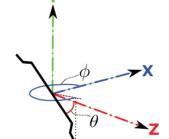


 \mathbf{l}^{1} unit vector $\parallel \mathbf{m}^{(1)} \Rightarrow$ $\mathbf{L}^1 = \mathbf{l}^1 \otimes \mathbf{l}^1$ – structural tensor

A structural tensor lays down the material symmetry needed to describe anisotropy of material - hyperelastic material: strain energy density, $W(\mathbf{E})$, \mathbf{E} -Lagrangian strain tensor, as a potential for the stress tensor

$$S_{ij}(\mathbf{E}) = \frac{\partial}{\partial E_{ij}} W(\mathbf{E}) \quad \Rightarrow \quad \frac{\partial S_{ij}}{\partial E_{kl}} = \frac{\partial^2}{\partial E_{ij} \partial E_{kl}} W(\mathbf{E}) = C_{ijkl}(\mathbf{E})$$

- orientation state of fibres can be quantified by the orientation distribution function (ODF) $f(\mathbf{n})$, where $\mathbf{n}(\theta, \phi)$ is a unit vector associated with the orientation of a rod-like particle (fibre) in space ODF is a probability of finding a fibre between the given



angles on a unit sphere (radius r = 1), such as: $P(\theta_1 \le \theta \le \theta_1 + d\theta, \phi_1 \le \phi \le \phi_1 + d\phi)$ $= f(\theta_1, \phi_1) \sin \theta_1 d\theta d\phi$

-l-order orientation tensor (OT) can be defined as follows:

$$O_{\mu_1\dots\mu_l} = \oint_{S^2} n_{\mu_1} \otimes \dots \otimes n_{\mu_l} f(\mathbf{n}) \mathrm{d}^2 n$$

- l-order alignment tensor (AT) is a deviatoric or irreducible part of the OT. The 2^{nd} order alignment tensor A_{ij} , which reads as:

$$A_{ij} = \oint_{S^2} \underbrace{\left(n_i \otimes n_j - \frac{1}{3} \cdot \operatorname{tr} \left(n_i \otimes n_j\right) \cdot \delta_{ij}\right)}_{\overline{n_i \otimes n_j}} f(\mathbf{n}) d^2 n = \oint_{S^2} \overline{n_i \otimes n_j} f(\mathbf{n}) d^2 n$$

represents the deviation of the OT from isotropy and specifies the main anisotropy directions of the system. Alignment tensor series can reconstruct the ODF. The expression for the approximation of the ODF using the 2^{nd} order AT is as follows:

$$f(\mathbf{n}) = \frac{1}{4\pi} \left(1 + \frac{(2\cdot 2+1)!!}{2!} A_{ij} \overline{n_i \otimes n_j} \right)$$

In the research:

- the eigenvectors $\{\mathbf{d}^i\}_{i=1,2,3}$ of the 2^{nd} order alignment tensor are utilized to define the material symmetry axes of SFRC, i.e. $\mathbf{d}^i = \mathbf{l}^i$

ODF $f(\mathbf{n})$ approximated using the 2^{nd} order AT is utilized to evaluate direction dependent elasticity constants of the composite γ^{ij} , G^{ij} in material symmetry directions

Material model for SFRC in material symmetry frame

– constitutive relation with the assumption of $\frac{\partial}{\partial x} \approx \frac{\partial}{\partial X}$ leading to linearised hyperelasticity $\mathbf{E} \approx \boldsymbol{\varepsilon}$

$$\mathbf{S}^{(c)} = \frac{\partial}{\partial \boldsymbol{\varepsilon}^{(c)}} W(\boldsymbol{\varepsilon}^{(c)}) = \underbrace{V^{(m)} \left(\gamma \mathbf{I} \operatorname{tr}(\boldsymbol{\varepsilon}^{(c)}) + 2G\boldsymbol{\varepsilon}^{(c)} \right)}_{\text{concrete, isotropic}} + \underbrace{V^{(f)} \left(\sum_{i,j=1}^{3} \gamma^{ij} \operatorname{tr}(\boldsymbol{\varepsilon}^{(c)} \mathbf{L}^{j}) \mathbf{L}^{i} + 2 \sum_{i,j\neq i}^{3} G^{ij} \mathbf{L}^{i} \boldsymbol{\varepsilon}^{(c)} \mathbf{L}^{j} \right)}_{\text{fibres, orthotropic}}$$

- orientation-weighted orthotropic 4^{th} order elasticity tensor

$$\mathbf{C}^{(c)} = \underbrace{V^{(m)} \left(\gamma \mathbf{I} \otimes \mathbf{I} + 2G^{<4} \right) \mathbf{I}^{S}}_{\text{concrete, isotropic}} + \underbrace{V^{(f)} \left(\sum_{i,j}^{3} \gamma^{ij} \mathbf{L}^{i} \otimes \mathbf{L}^{j} + \sum_{i,j \neq i}^{3} 2G^{ij} (\mathbf{L}^{i} \otimes \mathbf{L}^{j})^{S} \right)}_{\text{concrete, isotropic}}$$

Conclusions

- 1. Received measuring results proved that both DC-conductivity testing combined with photometry and X-ray micro-tomography have high accuracy and they can be applied in defining fibre orientations from real concrete samples reliably
 - both measuring methods offer possibilities to improve and develop the manufacturing process of SFRC products
- 2. Formulation of orthotropic linear-elastic constitutive model for SFRC based on the orientation state of fibres
 - model uses full orientation information of fibres
- model is independent of reference frame
- \bullet material symmetry axes are identified by the eigenvectors of the 2^{nd} order alignment tensor
- composite orthotropic material constants are assessed utilizing the orientation distribution function of fibres
- formulated constitutive model can directly be implemented into numerical analysing tools

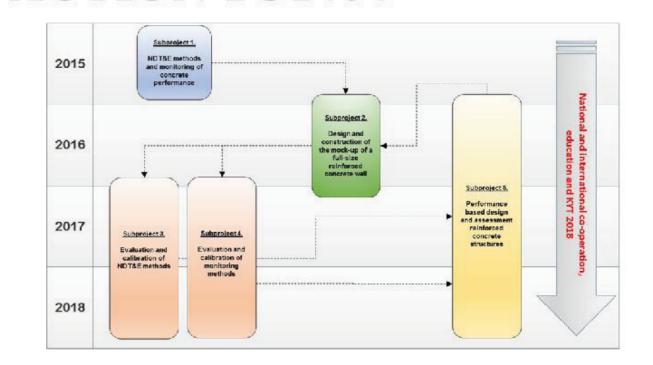
RESEARCH PROJECTS

Fahim Al-Neshawy; Esko Sistonen; Olli-Pekka Kari; Mari Eik; Jari Puttonen (firstname.surname@aalto.fi)

RECENT RESEARCH PROJECT RELATED TO THE COST ACTION TU1404

WANDA (2015-2018). Non-destructive examination of NPP primary circuit components and concrete infrastructure. The Finnish Research Programme on Nuclear Power Plant Safety (SAFIR2018).

http://virtual.vtt.fi/virtual/safir2018/management.htm



IMPORTANT PUBLICATIONS RELATED TO THE COST ACTION TU1404

Kari, Olli-Pekka (2015). Long-term ageing of concrete structures in Finnish rock caverns as application facilities for low- and intermediate-level nuclear waste. Helsinki: 2015. 144 p. (Aalto University publication series Doctoral Dissertations 9/2015 EXPOSURE SOLUTION http://urm.fi/URN:ISBN:978-952-60-6052-1

EXPOSURE SOLUTION

PHYSICAL ADSORPTION CHARGED SURFACE (-)

Industrial Physical Adsorption Charged Surface (-)

EDL PHYSICAL ADSORPTION CHARGED SURFACE (-)

Industrial Physical Adsorption Charged Surface (-)

Industrial Physical Adsorption Charged Surface (-)

EDL PHYSICAL ADSORPTION CHARGED SURFACE (-)

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EDL PHYSICAL ADSORPTION CHARGED SURFACE (-)

EDL PHYSICAL ADSORPTION CHARGED SURFACE (-)

ELIQUID PHASE

LIQUID PHASE

LIQUID PHASE

SOLUTION

Exposure

Free solution

Gaseous phase

Centre of the pore

Centre of the pore

Centre of the pore

Sistonen, Esko; Al-Neshawy, Fahim; Ferreira, Miguel (2015). Ageing Management Platform For NPP Concrete Structures. IABSE Workshop, Helsinki, Finland, February 11-12, 2015. Helsinki 2015, International Association for Bridge and Structural Engineering IABSE, pp. 280-287.



http://www.ril.fi/en/international-conferences/past-events/iabse-2015.html

Sistonen, Esko; Mutanen, Petri; Al-Neshawy, Fahim (2014). Development of a Database for the Restoration Mortars – von Konow DB. 1st International Conference on Ageing of Materials and Structures 2014 AMS'14, Delft, The Netherlands, 26-28 May 2014. pp. 40-47.

http://www.ams.tudelft.nl/

Eik, Marika (2014). Orientation of short steel fibres in concrete: measuring and modelling. Helsinki: Aalto University Department of Civil and Structural Engineering, 2014. 226 p. (Aalto University publication series Doctoral Dissertations 28/2014). http://urn.fi/URN:ISBN:978-952-60-5592-3 (more detailed in M. Eik et al. posters)

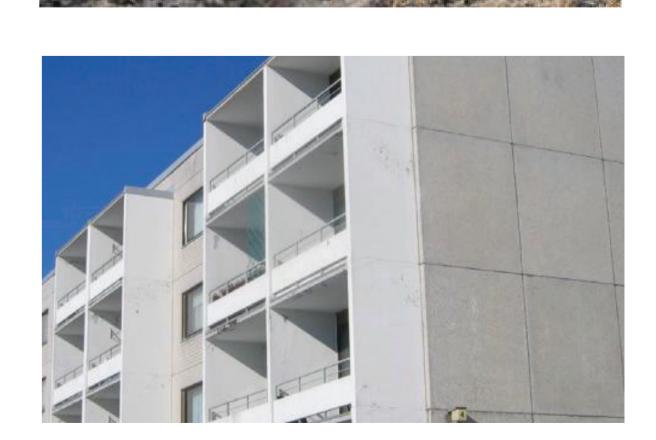
The GOVERNING BODY OF SUOMENLINNA

Thorborg von Konow was an appreciated researcher in the field of eatoration, her specialization being the ageing and analysis of older mortars.

Having worked the last years as a private consultant, her research was left without a natural continuation. Her material from over 20 years of research was left behind with three restoration architects, who presented the material to Aalto University Building Department as a starting opinifor a research no reparation mortars.

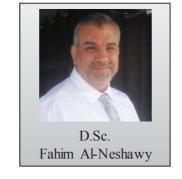
The database will be built from this material and it is the first part of the research project.

Al-Neshawy, Fahim (2013). Computerised prediction of the deterioration of concrete building facades caused by moisture and changes in temperature. Department of Civil and Structural Engineering. Aalto University publication series DOCTORAL DISSERTATIONS 96/2013. http://urn.fi/URN:ISBN:978-952-60-5203-8















The most important scientific projects of TUT Service Life Engineering of Structures group related to COST Action TU1404

Propagation of Reinforcement Corrosion in Existing Concrete Facades Exposed to Nordic Climate

Arto Köliö PhD project (2012-2015), arto.kolio@tut.fi

This study develops service life models for assessing the deterioration of concrete structures in real life conditions and their remaining service life. Finland has 60 million m2 of weather-exposed concrete facades whose maintenance is a challenge both as to its cost effects and the performance of the entire building stock. The service-life design method presently used in Finland does not consider the entire damage accumulation process which makes the calculated service life after formation of damage uncertain. The entire service life can be justifiably utilised by developing a service-life model that includes the damage propagation phase and takes reliably into account the impact of environmental stressors on deterioration rate.

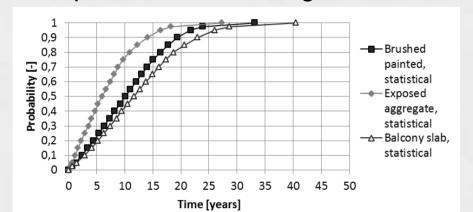
Papers:

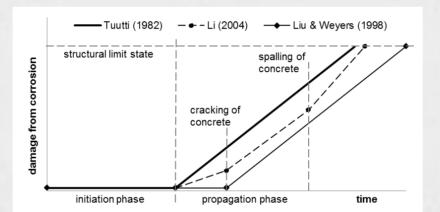
Köliö, A., Honkanen, M., Lahdensivu, J., Vippola, M., Pentti, M. 2015. Corrosion products of carbonation induced corrosion in reinforced concrete facades. Corrosion Science. Under review.

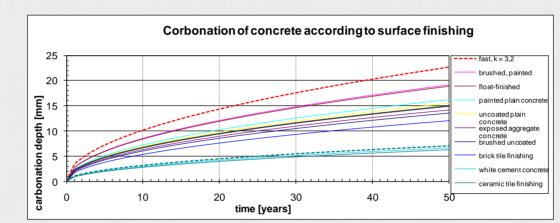
Köliö, A., Niemelä, P., Lahdensivu, J. 2015. Evaluation of a carbonation model for existing concrete facades and balconies by consecutive field measurements. Cement and Concrete Composites. Under review.

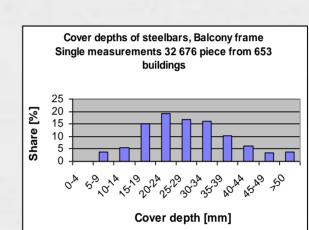
Köliö, A., Honkanen, M., Lahdensivu, J. 2015. Corrosion propagation phase studies on Finnish reinforced concrete facades. Proceedings of the 1st International symposium on building pathology. Porto, Portugal.

Köliö, A., Lahdensivu, J. 2014. Active corrosion time affecting visual corrosion damage in carbonated concrete facades. Eurocorr 2014. European corrosion congress. Pisa. Italy.









Adaptation to Climate Change in Existing Concrete Buildings

Toni Pakkala PhD project (2014-2017), toni.pakkala@tut.fi

The current Finnish building stock, and built environment in general, has formed quite lately compared to the rest of Europe. The majority of Finnish buildings date back to the 1960's to 1980's. The building stock is regenerating quite slowly, 1-2 % annually, meaning that today's stock will constitute a majority of the buildings also 50 years from now. Previous studies have found that climate change has only negative impacts on the durability and building-physical performance of structures. And since earlier research has shown that the durability properties of structures are inadequate in many respects, we will need to find means to adapt to climate change in order that the built environment remains technically usable.

Papers:

Köliö, A., Pakkala, T., Lahdensivu, J., Kiviste, M. 2014. Durability demands related to carbonation induced corrosion for Finnish concrete buildings in changing climate. Engineering Structures. Vol. 62-63. Pp. 42-52.

Pakkala, T., Köliö, A., Lahdensivu, J., Kiviste, M. 2014. Durability demands related to frost attack for Finnish concrete buildings in changing climate. Building and Environment. Vol. 82. Pp.27-41.

Durability Properties and Actual Deterioration of Finnish Concrete Facades and Balconies DSc. Jukka Lahdensivu (2006-2011), jukka.lahdensivu@tut.fi

Finnish multi-storey residential buildings have been built of precast concrete panels since the 1960's. Half of these buildings, which for the most part are located in suburbs, were built in the fairly short period 1960-1979. The durability properties and repair needs of existing concrete facades and balconies are key factors contributing to the technical performance of the built environment and the owners' economical decisions. The general objective of this research was to study the factors that have actually had an impact on the service life, occurrence and progress of deterioration in existing concrete facades and balconies.

This research was based on extensive material from condition investigations of existing precast multi-storey buildings (947) and related analyses. The key research areas have been the realised durability properties of concrete structures and the actual deterioration of structures under natural conditions. The results of this research allow developing service-life models for the existing already damaged building stock to better prepare for upcoming repair needs, both technically and economically, and to allow optimal scheduling of necessary repairs with respect to the service life of an existing structure.

Publications:

Lahdensivu, J., Mäkelä, H., Pirinen, P. 2013. Corrosion of reinforcement in existing concrete facades. In de Freitas, V. P., Delgado, J. M. P. Q. (editors) Durability of building materials and components, Building pathology and rehabilitation 3. Berlin. Springer. Pp. 253-274.

Lahdensivu, J., Varjonen, S., Pakkala, T., Köliö, A. 2013. Systematic condition assessment of concrete facades and balconies exposed to outdoor climate. International journal of sustainable building technology & urban development. Vol4:3 Pp. 199-209.

Lahdensivu, J. 2012. Durability properties and actual deterioration of Finnish concrete facades and balconies. Tampere. Tampere University of Technology. Publication 1028. Doctoral Thesis. 117 p + app. 37 p.

















Effect of interacted deterioration on concrete performance in cold environments (DURAINT Project)

Markku Leivo (Dr. Ing. – markku.leivo@vtt.fi) • Miguel Ferreira (PhD – miguel.ferreira@vtt.fi) VTT Technical Research Centre of Finland Ltd. Kemistintie 3, Espoo, P.O. Box 1000, FI-02044 VTT, Finland

Scope & Goals

A VTT project in cooperation with University of Aalto. The overall objective of the project was to evaluate the effect of interacted deterioration on the durability and service life of concrete structures.

It was expected that coupled deterioration is different for concretes with different binding materials. That is why concretes with added BFS or FA were also included as well as cements mixed with some BFS (CEM II/A-M(S-LL) 42,5 N/R and CEM II/A-LL42,5 R). BFS and FA were also included because they are used in Finland as additions when appropriate, e.g. to diminish hydration development, as well as to facilitate sustainable construction.

A desired service life closely linked with sustainability is always considered in the first place, and especially in aggressive environments including both carbonation and salt exposure.

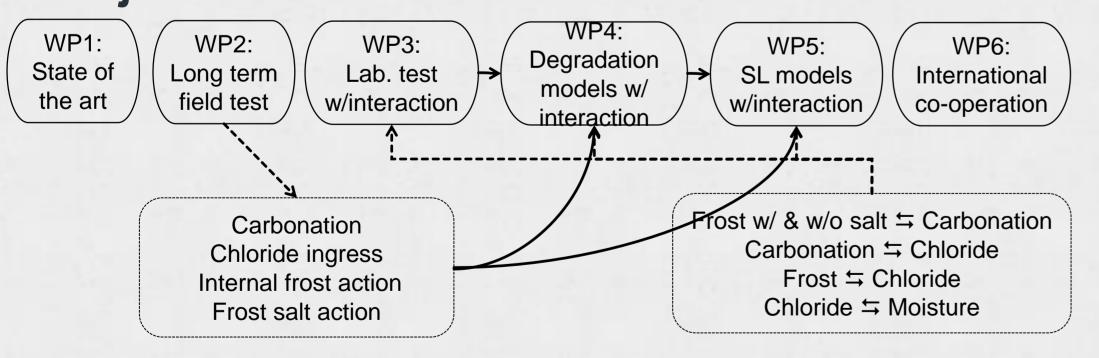
The study focuses on the following combinations:

- carbonation and freeze-thaw (effects on internal damage & moisture)
- carbonation and freeze-thaw + salt (affects on scaling)
- carbonation and chloride
- freeze-thaw and chloride (affects of internal cracking on chloride penetration)

Cycles and inverted procedures also used

- i.e. carbonation-freeze/thaw and freeze-thaw/carbonation

Project structure



Laboratory testing

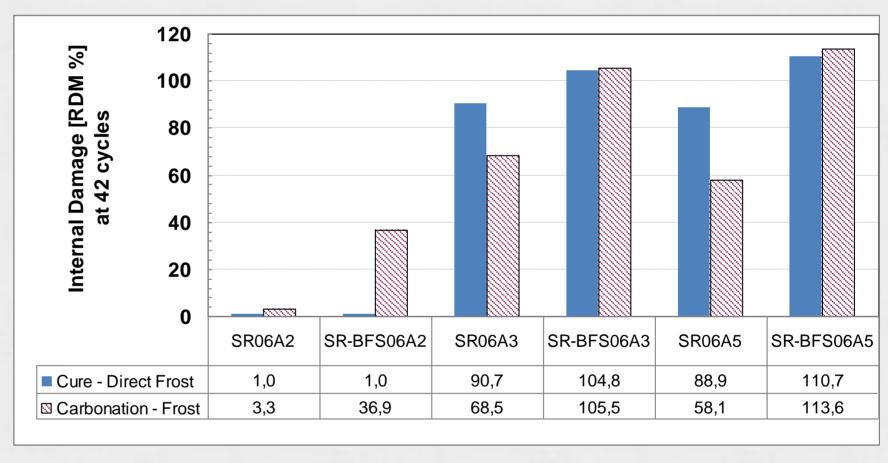
- Fresh mix properties (air content, AVA)
- Compressive strength (28, 90, 365 days)
- Freeze-thaw (Slab Test: CEN/TR 15177), scaling & internal damage
- Chloride ingress (NT Build 492), Ponding (profiles)
- Carbonation (EN 13295:1 & 4 % CO2; RH 60 %;T=20° C, sealed)
- Polished thin-sections microscopy

Mixtures and materials

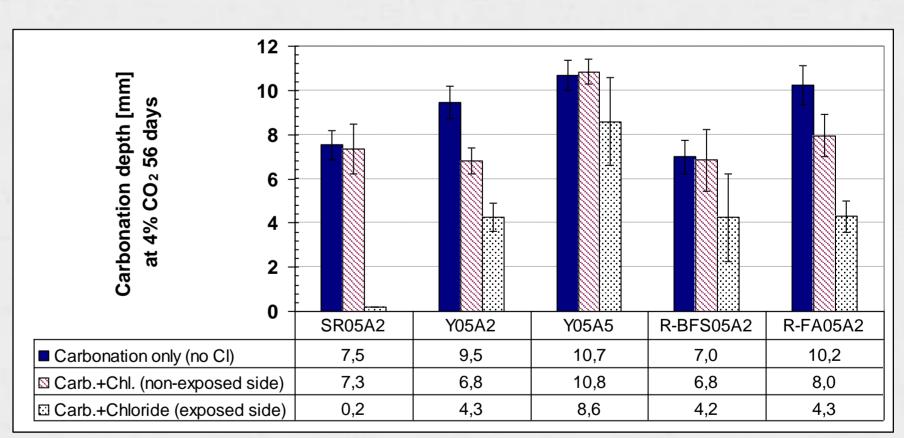
- $w/b_{effective} = 0.42 \text{ to } 0.60 \text{ (w/(cem+2SF+0.8BFS+0.4FA))}$
- 3 Finnish cement (CEM I or II 42.5), 217 to 450 kg/m³.
- Slag (up to 50%), fly ash (up to 25%) or silica fume (4%)
- Normal Finnish granite aggregate
- Compressive strength up to 60 MPa.

Approximately 40 concrete mixtures, representative of Finnish practice. A few mortar and pastes mixtures, for detailed studies. Mainly air entrained bridge concretes, some with no or inadequate air-entrainment. Including 6 air entrained façade or balcony concretes.

Some results: carbonation on plain freeze-thaw (internal damage): 50% BFS & varying air content



Some results: carbonation and chlorides



Main results

- Effect of aging on freeze-thaw scaling is remarkable carbonation has a negative effect with all binders. Effect of severe drying during carbonation test is a question.
- Effect of internal freeze-thaw damage on carbonation and chloride migration was much lower than expected
- Effect of carbonation on chloride migration is large
- Effect of chlorides on saturation degree in high humidity is large (water 65-75% with chlorides 85-98%)
- Interacted deterioration parameters can have remarkable effect on service life of concrete structures
- New knowledge acquired for material and product development









EARLY-AGE BEHAVIOR OF REINFORCED CONCRETE STRUCTURES

Farid BENBOUDJEMA
Laboratory of Mechanics and Technology, ENS de Cachan,

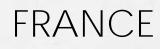






WG2 CO-LEADER



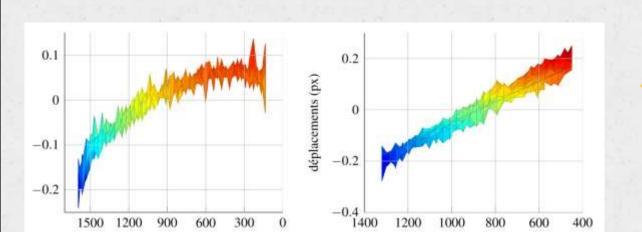


Experiments

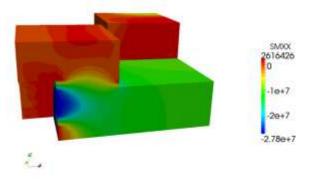
Biaxial creep testing with Digital Image Correlation analysis

FRANCE





Displacements field (DIC) without (left) and with Teflon (right) to get rid of edges effects



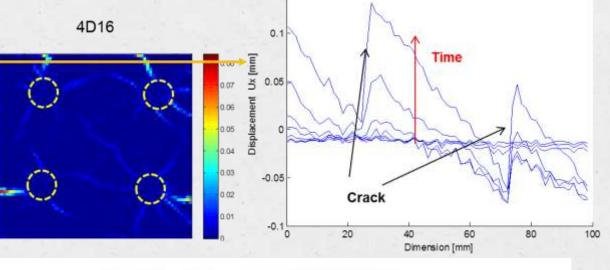
Numerical simulations

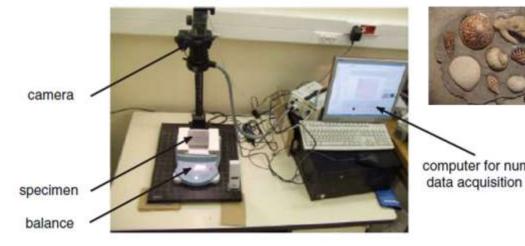
Lagier et al., *Engineering Structures*, 2011
Briffaut et al., Construction and Building Materials, 2012

ANR ECOBA PROJECT (Massive mock-up) tested at GeM (Nantes, France)

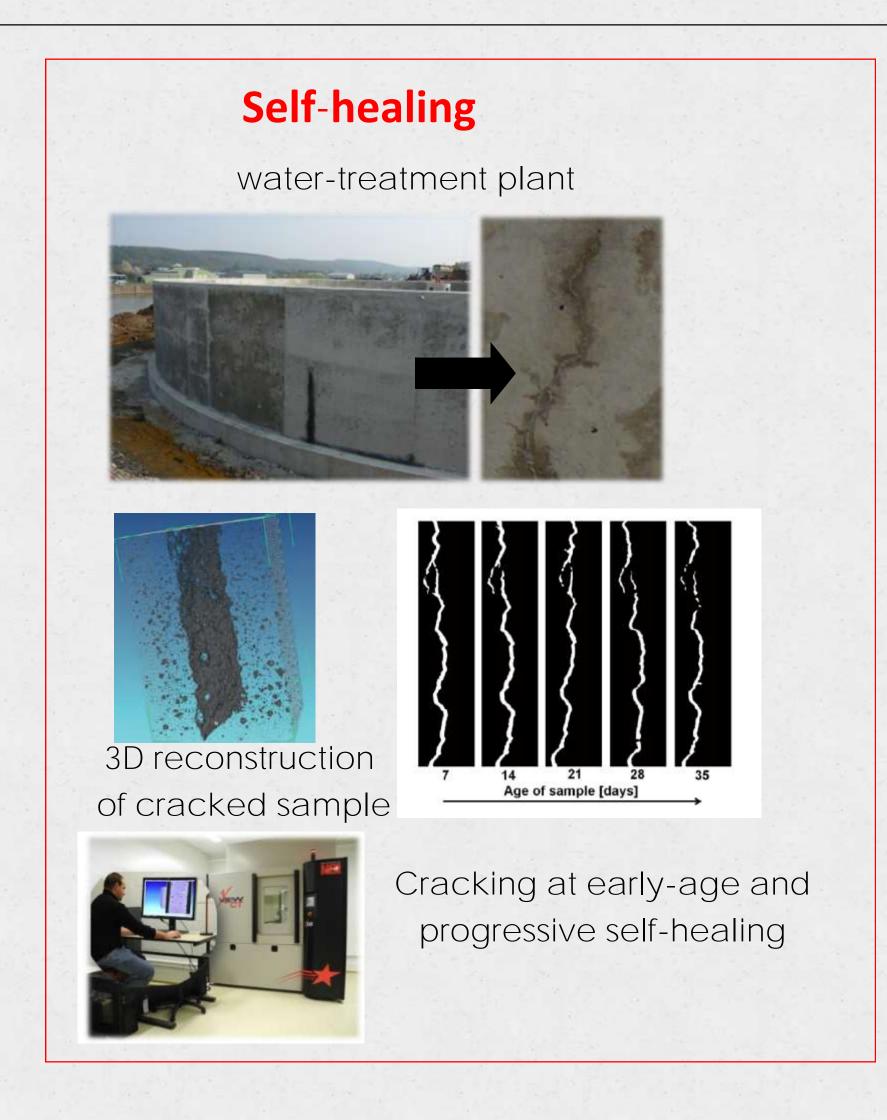


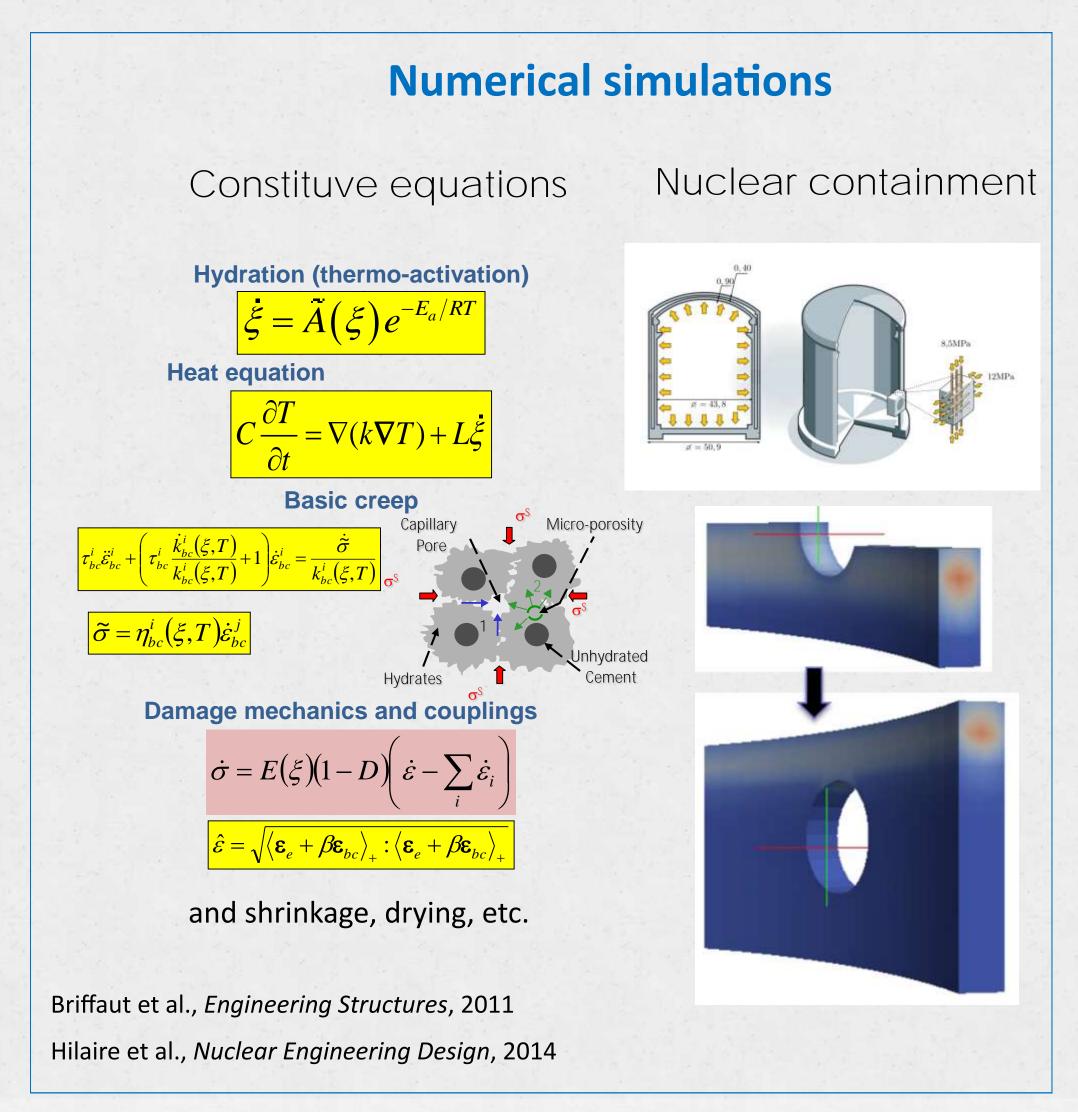
DIC analysis of cracking around aggregates due to shrinkage restraint





Evolution of hydration in cement paste Use of a « forest burning » type algortihm to extract the load bearing part of the microstructure Initial pixels Pixels found in the percolated path Prediction of the Young modulus evolution (without fitted parameters) Stefan et al., Computational Materials Science, 2010







Matthieu BRIFFAUT

Aveline DARQUENNES

Adrien HILAIRE

Fabien LAGIER
Ahmed LOUKILI
Georges NAHAS

Kelly OLIVIER
Emmanuel ROZIERE
Lavinia STEFAN















Early age mechanical behaviour of concrete



BOULAY C. - RAMANICH S. - BABY F. - TOUTLEMONDE F. - TORRENTI J.M.

Autogeneous shrinkage

Autogeneous strains measurement of concrete

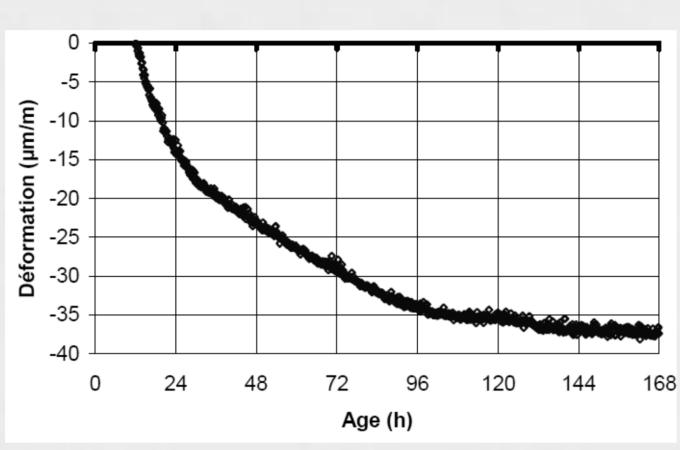
Setting time determination: Initiation BTJADE measurements





BTJADE

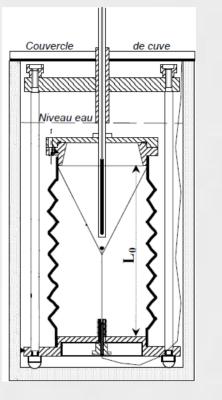


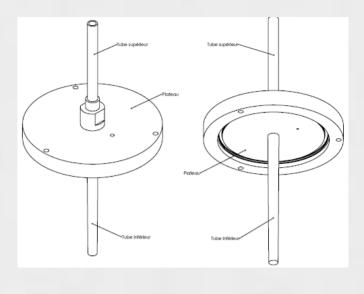


Calorimetry

Adiabatic and Quasi adiabatic calorimetry (heat released, Activation energy)

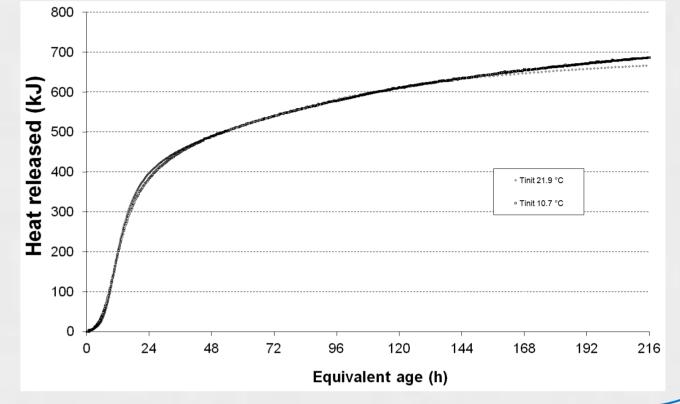




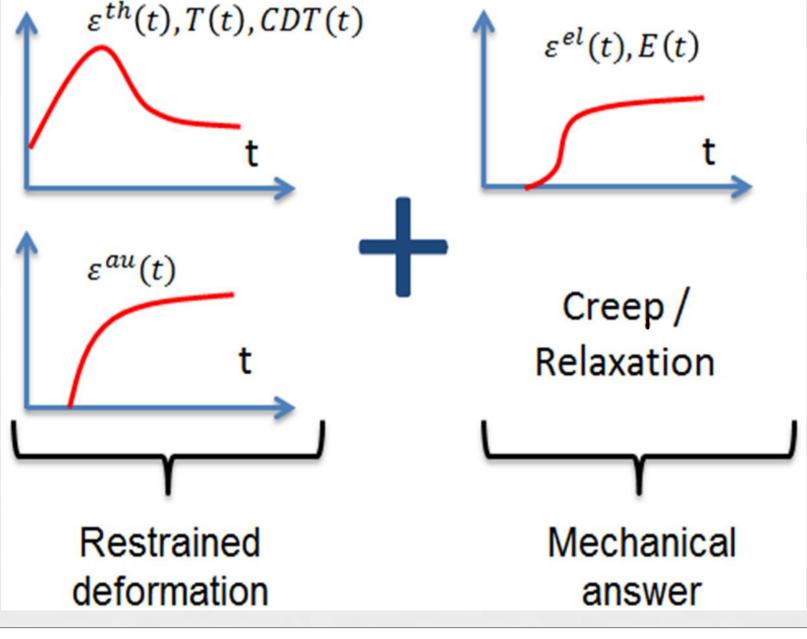




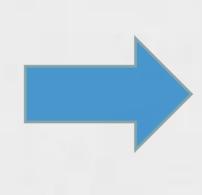


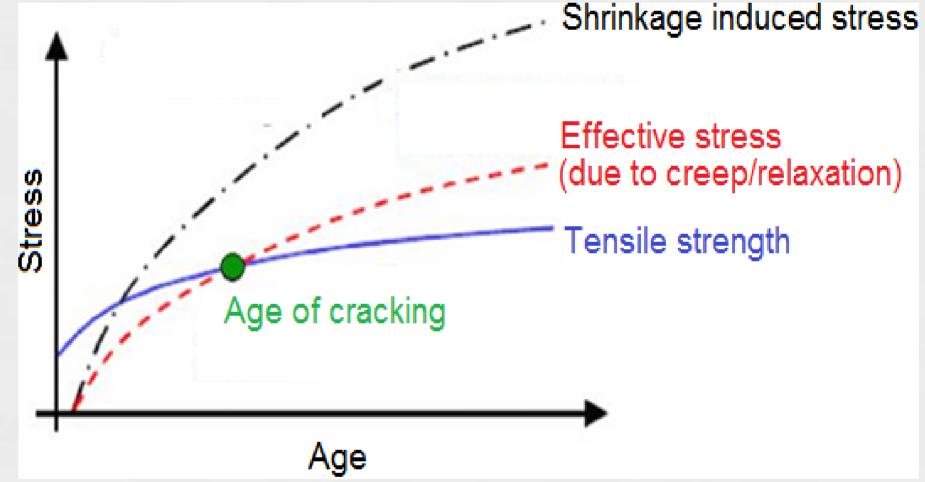


Background



After setting, mechanical properties of the concrete increase very fast during few hours.





(Delsaute et al., 2014)

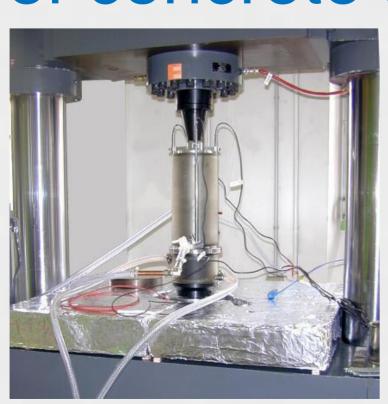


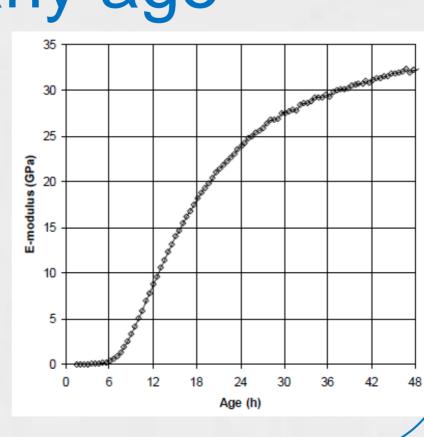
In case of restrained deformation

Need to know the evolution at early age

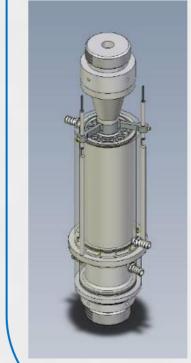
Elastic and viscous properties of concrete at early age

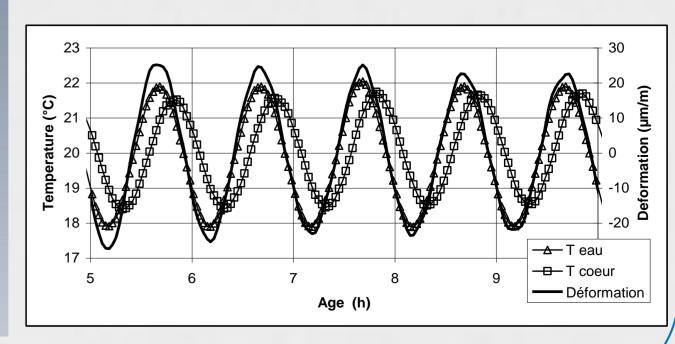






Coefficient of thermal expansion at early age















Multi-scale and Multi-physics approaches for analysis of the vulnerabilities and the materials used in the structure by experiments and modeling



Keywords: risk, vulnerability of structures, concrete material, geomaterials, wooden structures, dynamic behavior, thermomechanical, transfers, delayed behavior, aging, durability, severe stresses, seismic, impact, high temperatures, experimental platform, multiscale modeling coupling finite elements - discrete elements

goals:

Major themes:

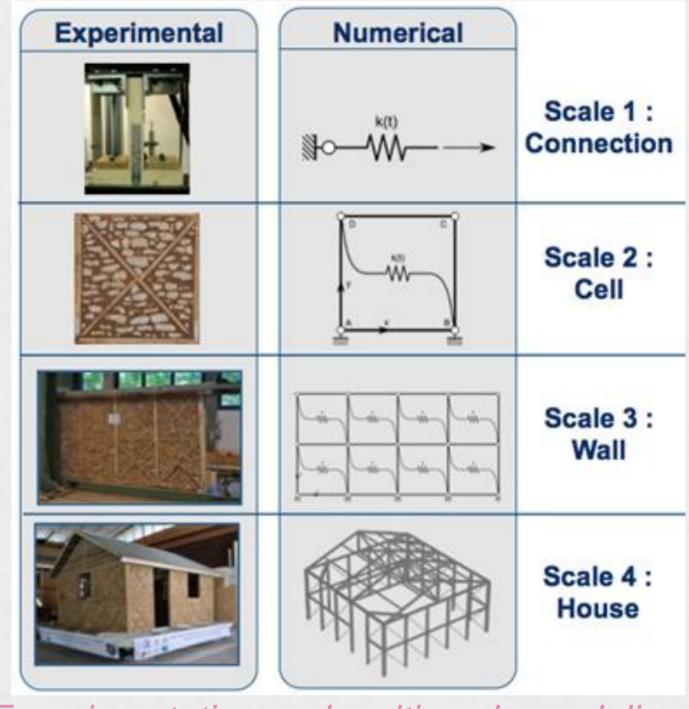
- Geomatrials under severe stresses
- Structures under seismic loading
- Structures under impacts or explosions
- Thermomechanics of concrete and structures
- Transfers in cementitious materials
- Delayed behavior and aging

Some applications:

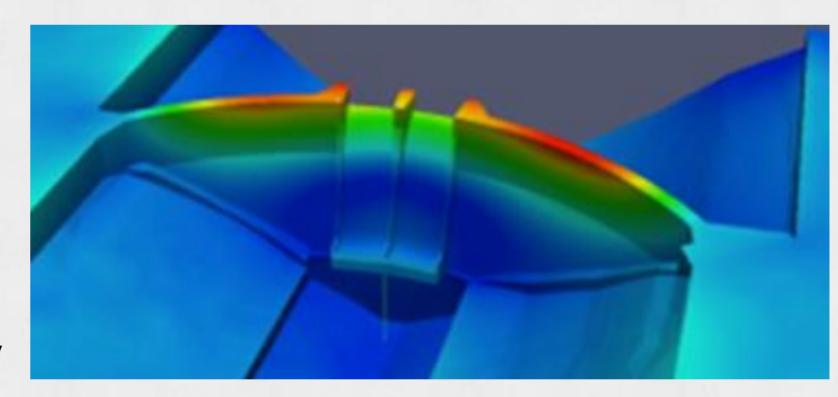
- Infrastructure vulnerability under extreme loads
- Parasismic wood-frame buildings
- Structure health monitoring
- Deep drilling in hard rock

Knowledge:

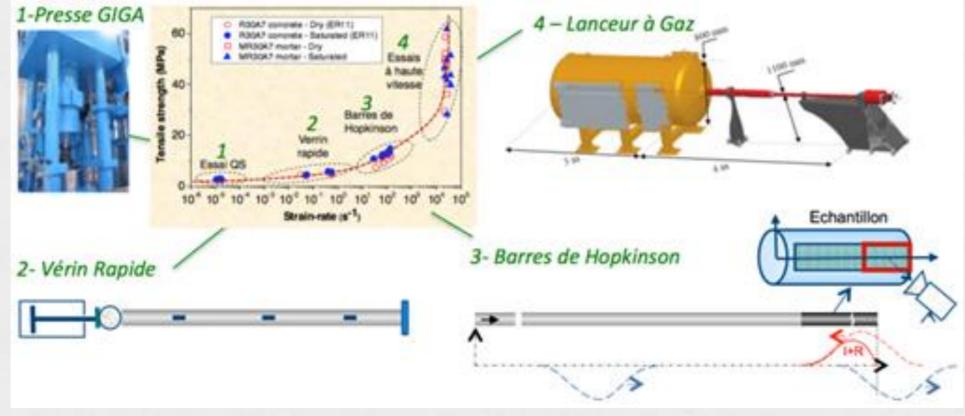
- Experimental mechanics
 - Dynamic Experimentation Platform
 - Rapid imaging and field measurements
 - Triaxial tests under extreme stress
 - High temperature experiments
- Numerical modeling and developments
 - Coupled models of damage and plasticity
 - Discrete or continuous mesoscopic models constructed from tomographic images
 - Multiscale modeling and multi-domain coupling Finite Element and Discrete Elements



Experimentation and multi-scale modeling to study seismic behavior of wooden frame houses filled by soil in Haiti.



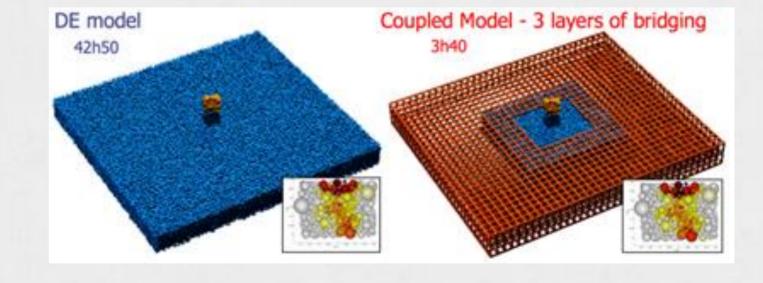
Numerical model of a dam used for the development of physical-statistical models for monitoring of structures under thermo-mechanical loading



Dynamic experimental platform to cover many types of loads to a wide range of strain rates.

Laboratory Sols, Solides, Structures, Risques
Domaine Universitaire - BP53 / 175 rue de la passerelle 38041 Grenoble cedex 9

www.3sr-grenoble.fr / direction@3sr-grenoble.fr



Coupled model multi-domain Discrete
Elements - Finite Elements for simulating
impacts on protection of reinforced
concrete structures.







Zhao

Researchers:

J. Baroth, M. Briffaut,

L. Daudeville, F. Dufour,

J. Mazars, E. Ouedraogo

H. Algusab, H. Benniou,

Dandachy, Z.Kammouna,

E. Koufoudi, A. Lau, A.

E.Piotrowska, M. Tatin,

F. Vieux-Champagne, G.

M. Boucher, P. Bui,

M. De Biaso, M. El

Mazurel, A. Omar,

PhD Student:

S. Capdevielle,

P. Forquin, S. Grange,

Y. Malécot, P. Marin,









Represented by: M. Briffaut (co-leader GP2c)



Keywords: Vulnerability of structures, concrete material, thermomechanical, transfers, delayed behavior, aging, durability, multi-scale modeling coupled finite elements

Major themes:

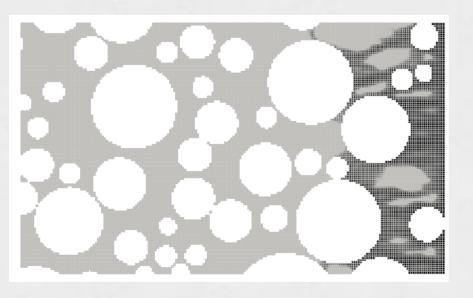
- Experimental study of concrete cracking sensibility of early age massif structrues
- Numerical modelling of early age behaviour of massive structures
- Mesosopic simulation to emphazise early age and drying behaviour particularity
- Massive concrete structures monitoring

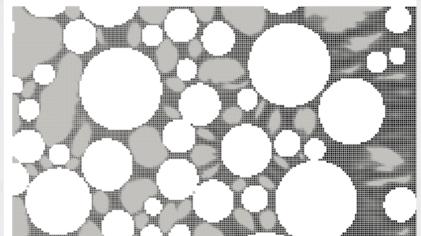
Some applications:

- Early age cracking of tunnel reinforcement
- Early age cracking of massive wall
- Leakage throught a crack prediction

Knowledge:

- Experimental mechanics
 - Creep test
 - Ring test
 - Permability test
 - Interface shear test
- Numerical modeling and developments
 - Coupled modelling between damage and permeability
 - Continous mesoscopic modelling build from tomographic images or granular curves
 - Chemeo thermo mechanical modelling of structures





Mesoscopic simulation of concrete cracking during drying process [4]



Ring test before casting

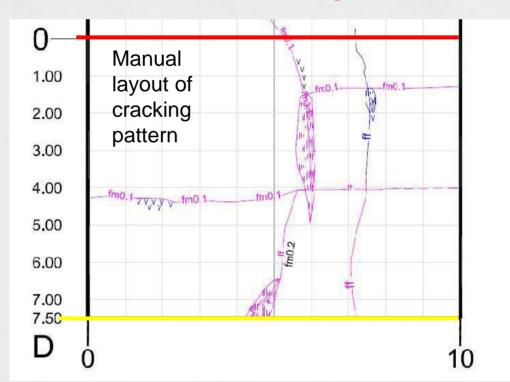


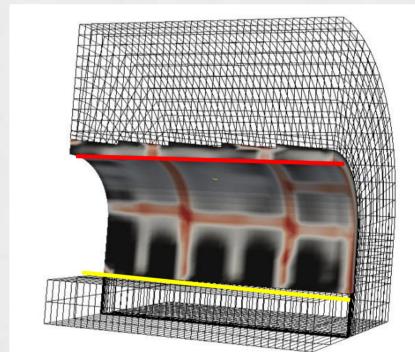


Ring test with rebars and construction joints

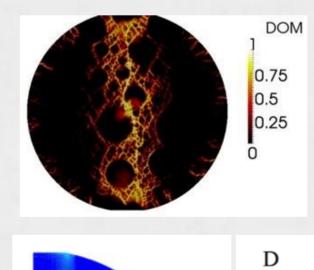
Ring test after casting

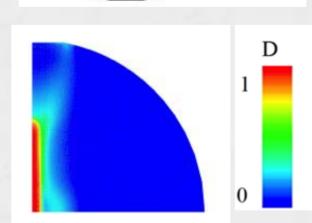
Thermal active ring test to study the cracking sensitivity of concrete (effects of rebars, construction joints, fibers,)[1]

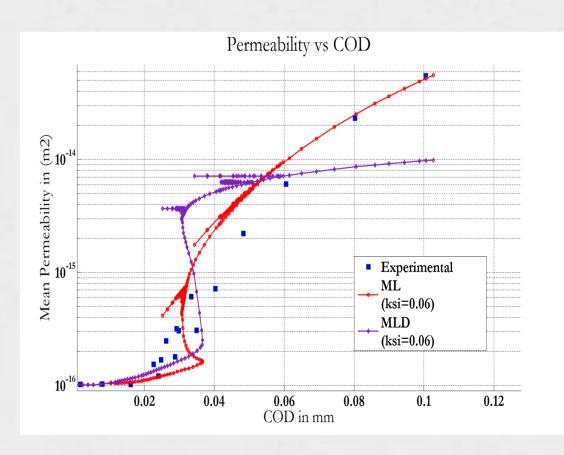




Comparison between manual cracking pattern layout and damage pattern prediction [2]







Structural permeability increase through a crack by mesoscopic or homogenous simulation [3]

- [Briffaut et al. 11] A thermal active restrained shrinkage ring test to study the early age concrete behaviour of massive structures, CCR.
- [Briffaut et al. 15] CMS Workshop "Cracking of massive concrete structures"
- [El Dandachy et al., 15] Numerical coupling between damage and gas permeability for concrete applied on a 3D splitting test, Coupled Problems
- [Briffaut and Benboudejma, 13] Numerical analysis of cracking induced by drying shrinkage in concrete using a mesoscopic approach: influence of aggregates restraint and skin effect, Concrep 8.

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Researchers:

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PhD Student:

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Z.Kammouna, M. Tatin, E.

M. Boucher,

Stavropoulou

Dufour, Y. Malécot,









LAFARGE Research Center Research related poster

Durability Aspects

- Gaz permeability,
- Chloride diffusion,
- Water porosity,
- Carbonation

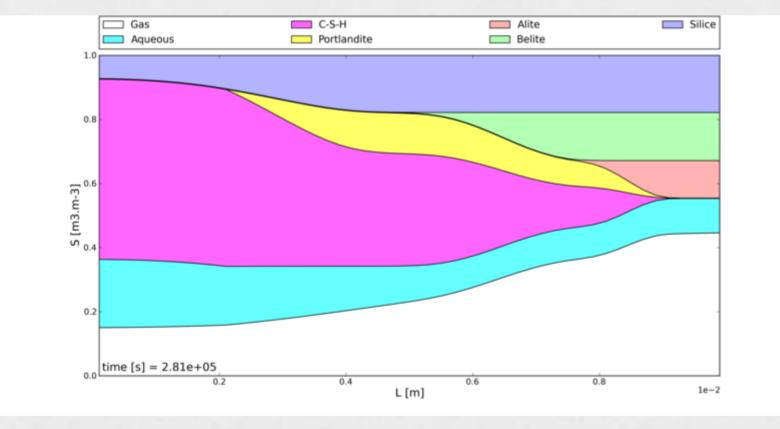
Experimental characterization and predictive models

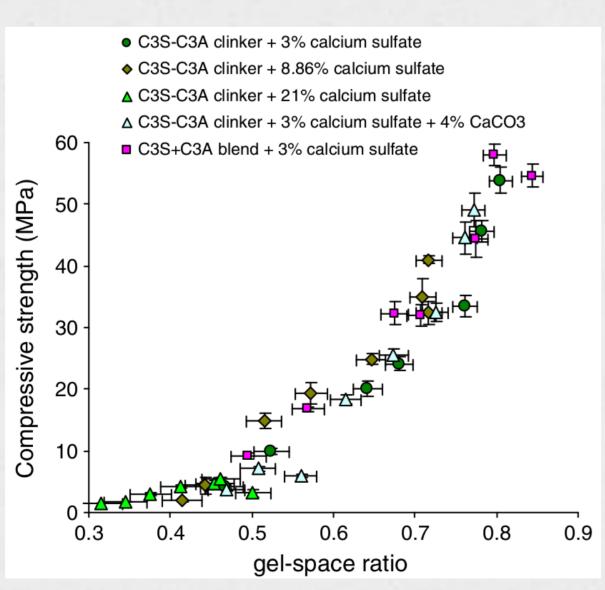




Hydration

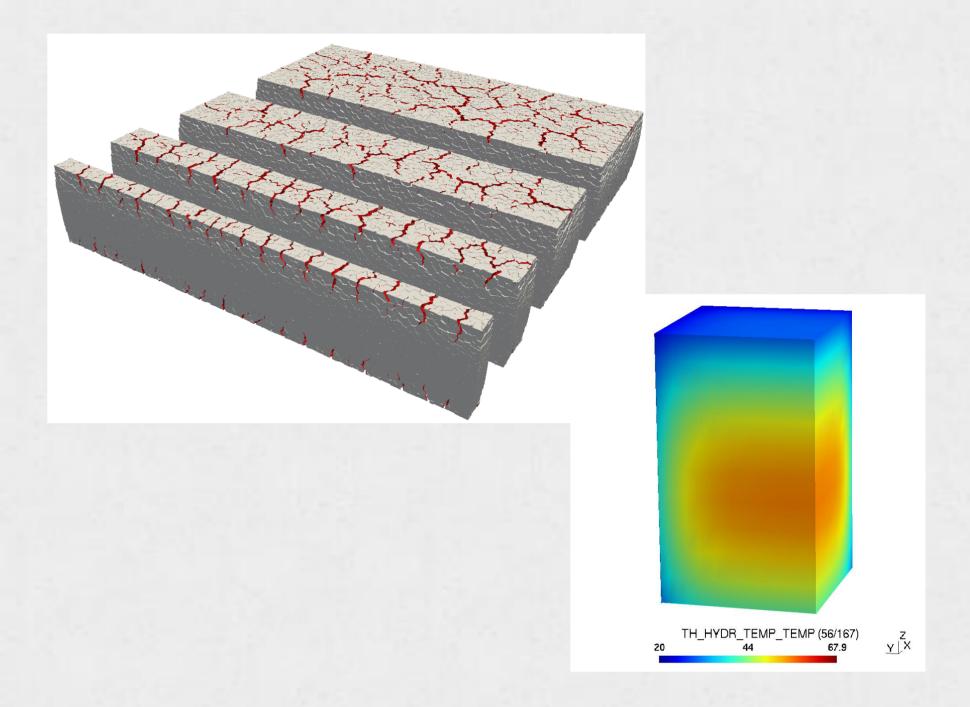
- Hydration kinetics,
- Hydration/drying coupling





Early age behavior modeling

- Autogenous, drying, thermal shrinkage
- Relaxation and creep
- Early-age cracking



Short and long term properties of concrete

- Mechanical properties
- Relaxation and creep













EFFECTS OF TEMPERATURE AND MOISTURE ON THE FRACTURE ENERGY OF CONCRETE

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CONTEXT

This main scope of this study is to improve the knowledge of the hydro-thermal behaviour of concrete. The main application concerns the containment chamber of nuclear power stations in order to predict their behaviour during severe accident. Thus, it is necessary to know perfectly the evolution of the thermal and mechanical properties of concrete under temperature and relative humidity controlled conditions.

OBJECTIVES

The main objective is the determination of the mechanical properties and mainly G_f (fracture energy), under hygrothermal controlled conditions. The principal encountered difficulties are : the balance setting of samples at different degrees of saturation and Gf measurements under pressure. In view of carrying out pressure tests later in the study and of minimizing the sample size and the volume under pressure, a very compact test was selected to measure Gf: disk-shaped compact tension (DCT) test.

In the event of severe accident:

- ❖ Temperature up to 160 ° C
- Pressure up to 5 bars
- Water vapor saturation



experimental conditions

Temperature: 30 ° C, 90 ° C, 110 ° C, 140 ° C et 160 ° C Degrees of saturation of concrete samples: 36%, 52%, 68%, 95% et 100% Pressure until 5 bars

DEVELOPMENT OF THE EXPERIMENTAL DEVICES (G, MEASURES) AND SAMPLES BALANCE SETTING

EST (DISK-SHAPED COMPACT

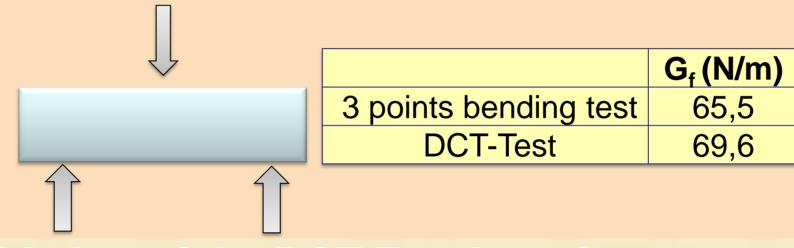
Choice of the DC1 test:

- Compact test
- Valid choice in anticipation of the tests under pressure
- Necessity of some adjustments since this test is not commonly
- ❖ employed for G_f measures

diameter: 15 cm thickness: 5 cm



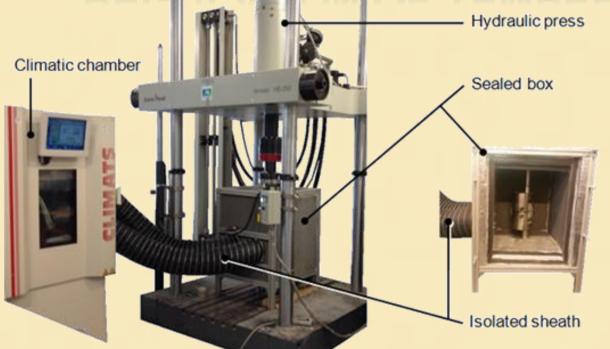
Comparison with 3 points bending test



- LVDT sensor Rollers Opening notch transducer Specimen Helmet

Validation of the DCT-Test in order to measure Gf

REGULATION OF TEMPERATURE AND RELATIVE HUMIDITY



Development of the equipment to control temperature and relative humidity during DCT tests:

- Sealed box that surrounds DCT test device
- 2 sealed sheath that link the climatic chamber and the sealed box
- Fan to homogeneize the temperature inside of the sealed box

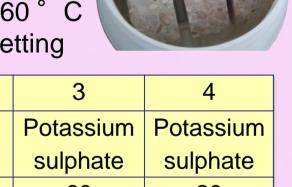
Temperature gap lower than 1° C and relative humidity gap lower than 3 % in the box

SAMPLES BALANCE SETTING

Use of salt solutions:

Sealed plastic containers that contain samples and saturated salt solutions

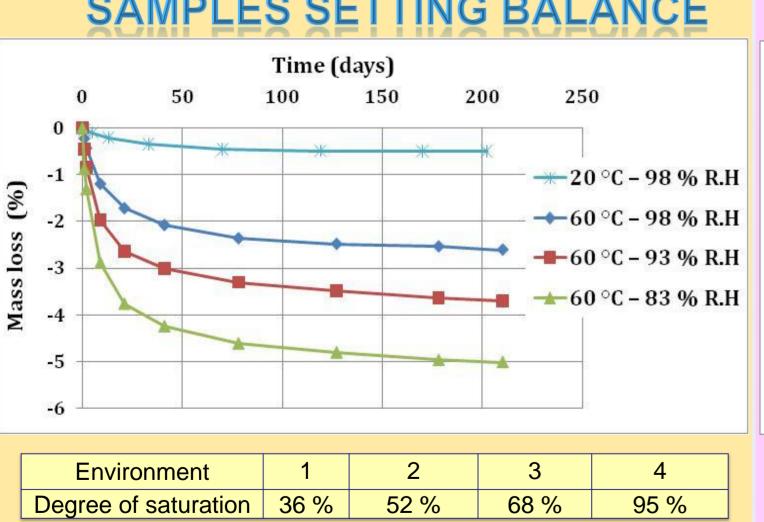
❖ Some containers are placed at 60 ° C in order to accelerate the balance setting



Environment	1	2	3	4
Salt solutions	Potassium	Potassium	Potassium	Potassium
Sail Solutions	chloride	nitrate	sulphate	sulphate
Temperature (°C)	60	60	60	20
Theoretical R.H. (%)	81	85	95	98
Measured R.H. (%)	83	93	98	98

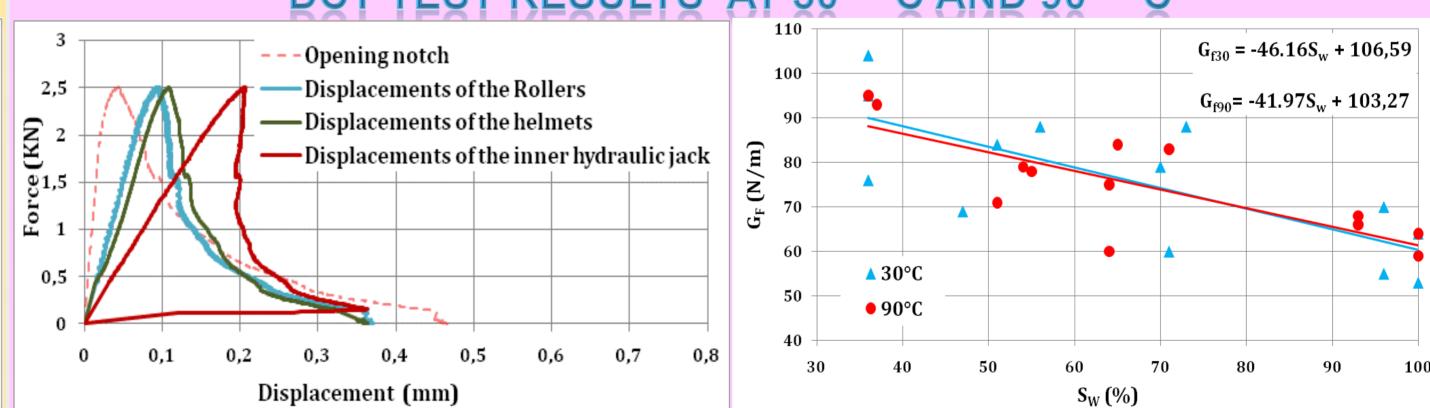
RÉSULTATS D'ESSAI

SAMPLES SETTING BALANCE



Sample preparation allows to test samples at four different levels of degree of saturation from 36 to 95 % that are representative of concrete states in a containment chamber.

TEST RESULTS AT 30° C AND 90° C



Different displacements measures are taken during the tests to highlight results consistency. The most reliable measures are taken by the rolls displacements, corresponding to the force application point. It is noticeable that displacements provided by the press jack transducer, give also a good evaluation of the fracture energy. This consideration is interesting in the perspective of the tests under pressure.

Tests results show that fracture energy decreases as degree of saturation increases. This trend is linear between 36 and 100 %.

CONCLUSIONS AND PERSPECTIVES

This study resulted in the determination of the fracture energy evolution depending on temperature and water degree of saturation of the concrete (S_w). The conditions during the tests were: two temperature (30 ° C and 90 ° C) and five different degrees of saturation varying from 36 to 100 %. A reduction of the fracture energy with the increase of the degree of saturation has been highlighted.

This study will be developed by performing tests in different conditions of temperature and relative humidity. Furthermore, numerical simulations has been carried out by means of two softwares Cast3M and Aster with the finite elements method. These simulations will allow to highlight the influence of the determined properties on the behaviour of the concrete structures.













THCM modelling for the assessment of large concrete structure service life





Laurie BUFFO-LACARRIERE*, Stéphane MULTON, Alain SELLIER, Jérôme VERDIER, Thierry VIDAL

*For more information: buffo-lacarriere@insa-toulouse.fr, +33 5 61 55 99 07

Parternership













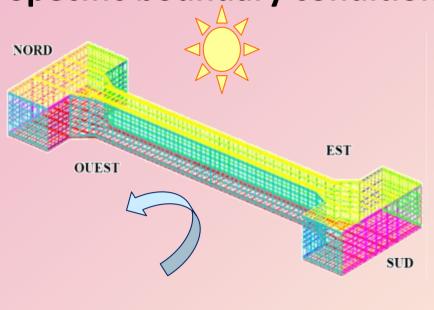


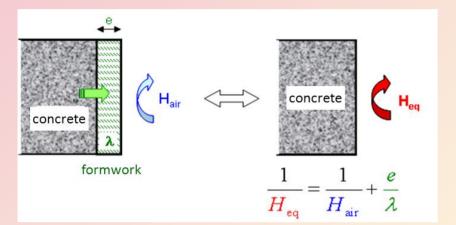


TC **CMS**

Thermal behaviour

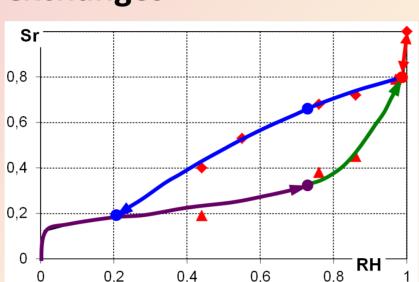
- Strong coupling with chemical evolutions
- Specific boundary conditions





Hygral behaviour

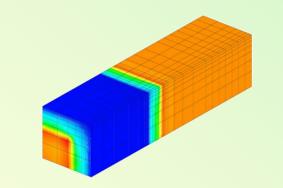
- Strong coupling with chemical evolutions
- Temperature effects on water exchanges



Degradations

- Effect of high temperature on paste chemical composition
- Leaching or acid attack

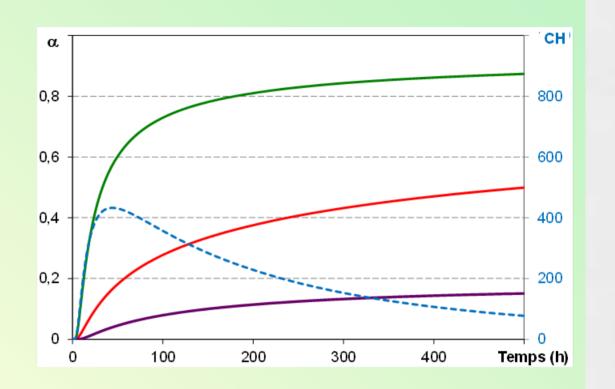
DEF



Specimen subjected to calcium leaching (blue zone = decalcified)

Hydration

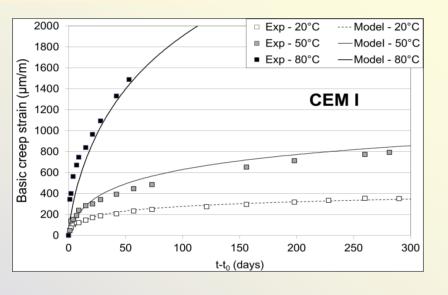
- Multiphasic hydration model for blended cements
- Chemical evolution in the long term (changing stoichiometry)

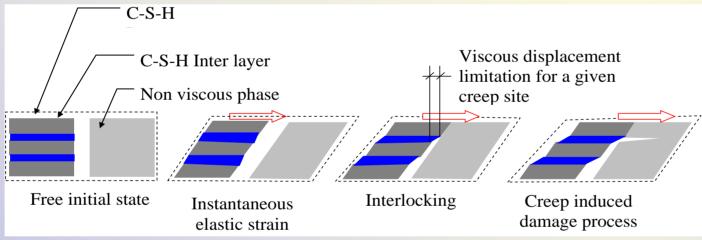


Hydration degree for components of the blended cement (clinker, SF and slag) Calcium hydroxide content

Creep

- Non linear visco-elastic model
- Coupling with chemical variations (hydration/degradation)
- Coupling with temperature (activation and thermal damage)



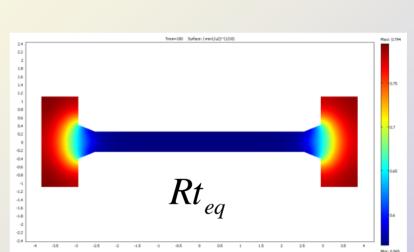


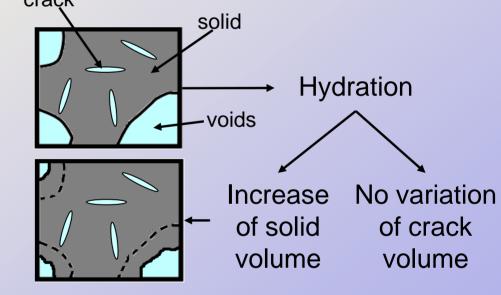
Damage - Cracking

- Anisotropic damage model with crack reclosure
- Volume effect (strength depends on the loaded volume)

LONG TERM

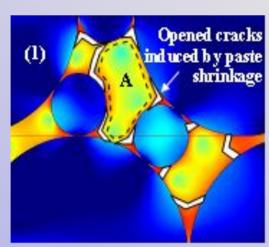
Coupling with hydration

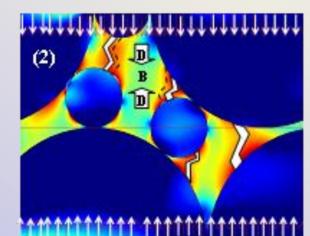




Poromechanics

Intra-poral pressures applied on rheological model (shrinkage, AAR, DEF)



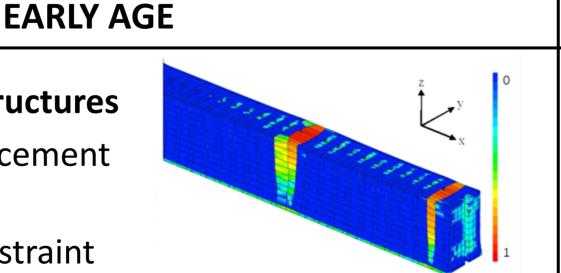


RC behaviour

- Modelling of steel-concrete bond
- Effect of hydration on bond properties

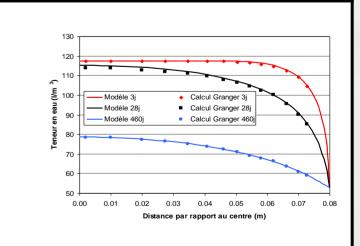
Reinforced concrete structures Nuclear Influence of reinforcement power on cracking pattern

External-internal restraint



In-service behaviour and effect of nuclear accident

- Dessication creep
- Effect of high temperatures

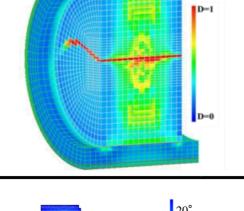


Nuclear waste storage

plants

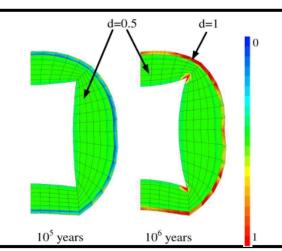
Massive structures with lowpH concrete

⇒ Early age behaviour of lowpH concretes



Storage disposal in deep geological formations

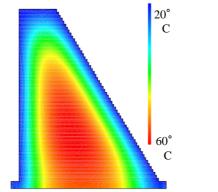
Impact of chemical variation in the long term



Dams Bridges

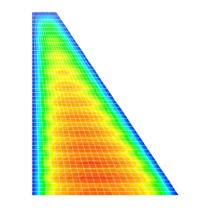
Massive structures

- ⇒ Concreting sequence
- ⇒ Material variability



Swelling reactions

Poromechanics for AAR and RSI









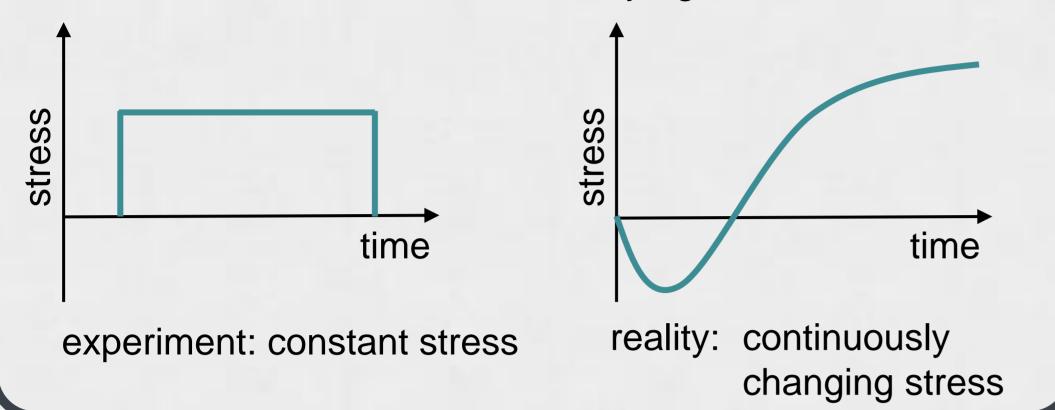


Creep of early age concrete under constant and variable stress

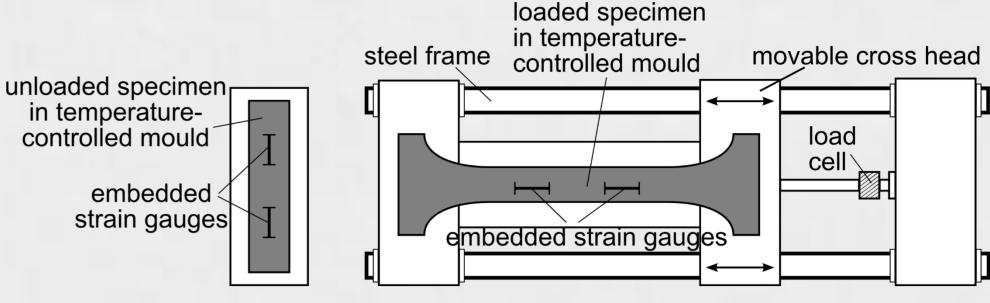
Wibke Hermerschmidt, TU Braunschweig iBMB/MPA

Motivation

- Early age concrete shows intense viscoelastic behavior that has great impact on stress and crack development
- Usual tests are carried out under constant stress, but in real concrete members stress varies with time
- Applicability of superposition principle has been shown for hardened concrete, results for early age concrete are rare



Experimental program



- Temperature stress testing machine (TSTM) allows investigation of viscoelastic behaviour at very early ages
- Creep tests under constant stress
 - → describe influence of hardening process on viscoelastic behaviour
 - → calibrate rheological model
- Creep tests under variable stress
 - → check applicability of superposition principle

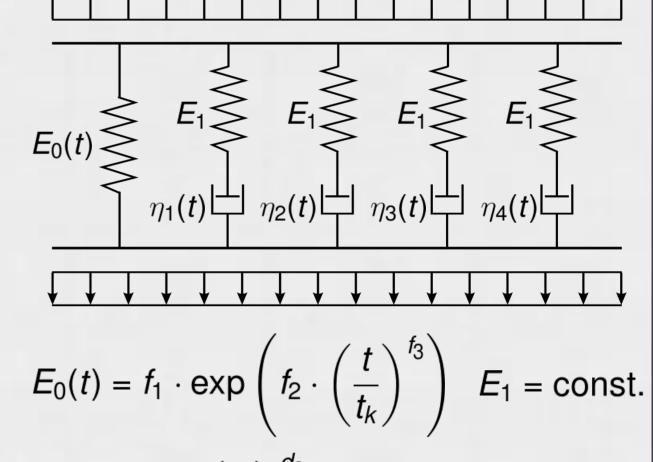
Rheological modeling approach

- Basic idea: generalized Maxwell model, 4 Maxwell units + 1 spring in parallel, aging parameters
- Constitutive equation

$$a_{0} \cdot \sigma + a_{1} \cdot \frac{\partial \sigma}{\partial t} + a_{2} \cdot \frac{\partial^{2} \sigma}{\partial t^{2}} + a_{3} \cdot \frac{\partial^{3} \sigma}{\partial t^{3}} + a_{4} \cdot \frac{\partial^{4} \sigma}{\partial t^{4}} = b_{0} \cdot \varepsilon + b_{1} \cdot \frac{\partial \varepsilon}{\partial t} + b_{2} \cdot \frac{\partial^{2} \varepsilon}{\partial t^{2}} + b_{3} \cdot \frac{\partial^{3} \varepsilon}{\partial t^{3}} + b_{4} \cdot \frac{\partial^{4} \varepsilon}{\partial t^{4}}$$
where $a_{0} \dots a_{4} = f(E_{i}, \eta_{i})$ $b_{0} \dots b_{4} = f(E_{i}, \eta_{i})$

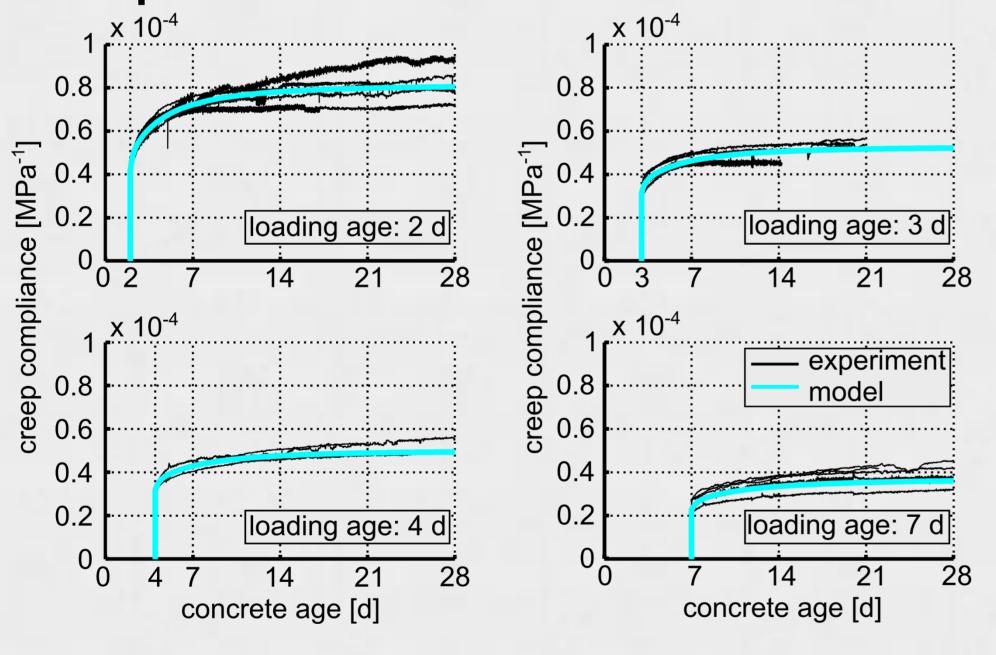
(solved numerically using MATLAB ode23s solver)

- Creep tests under constant stress are used for parameter fitting
- Differential model formulation allows efficient implementation into numerical simulations $\eta_i(t) = d_{1,i} \cdot \left(\frac{t}{t_{\nu}}\right)^{d_2}, i = 1 \dots 4$



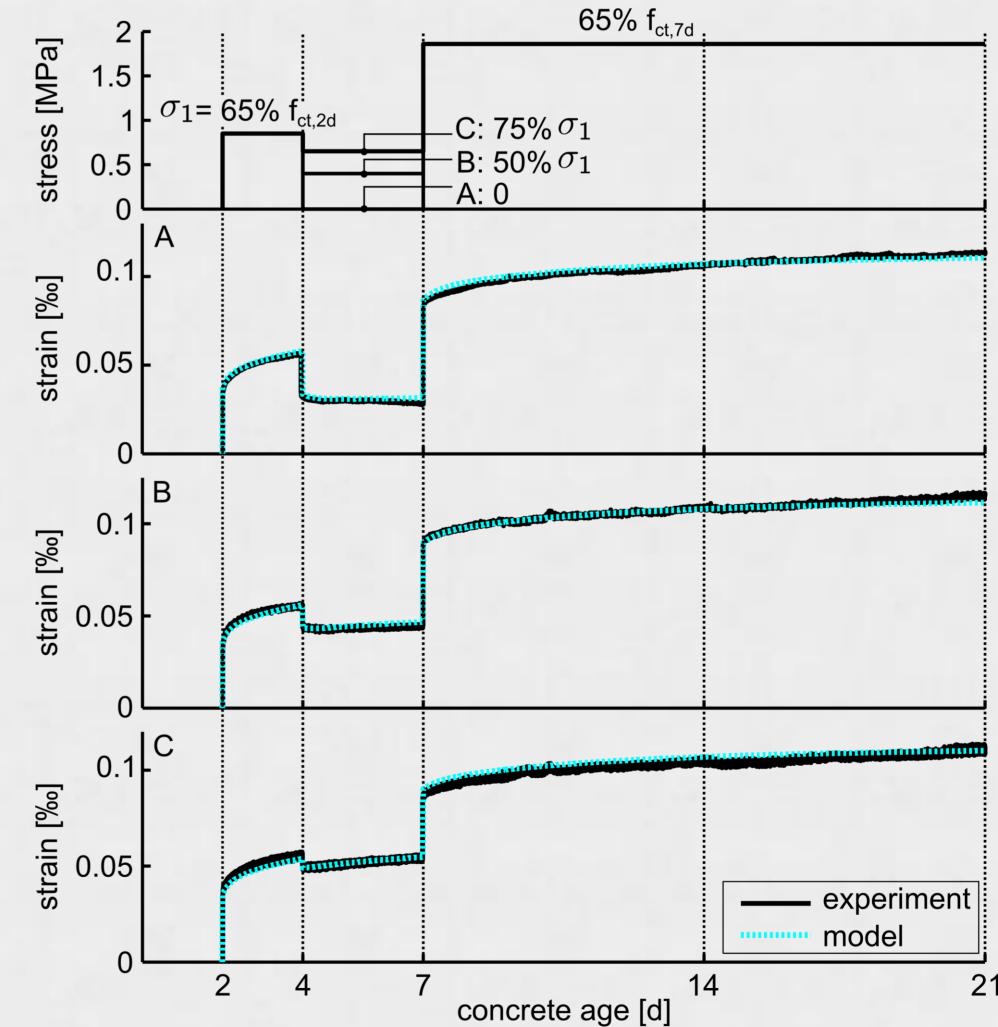
$$\eta_i(t) = d_{1,i} \cdot \left(\frac{t}{t_{\nu}}\right)^{d_2}, \quad i = 1 \dots 4$$

Creep under constant stress



- Creep tests with different loading ages show that the viscoelastic potential decreases with increasing concrete age
- Rheological model is able to decribe this behavior adequately through continuously aging parameters

Creep under variable stress



Comparison of different stress histories shows the influence of preloading on creep in following loading phases

 Good agreement of model and experiment indicates validity of superposition principle for early age concrete

Research institution:





Contact: w.hermerschmidt@ibmb.tu-bs.de

Financial support:

Forschungsgemeinschaft







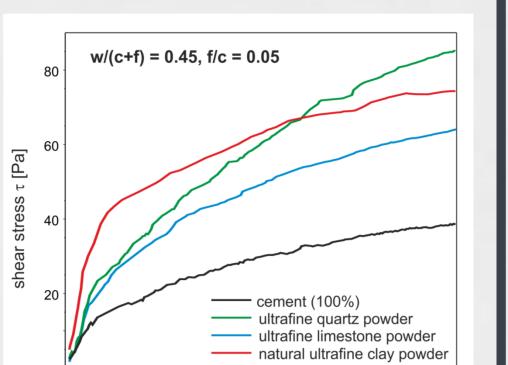
Influence of fine inert mineral additions on the hydration kinetics and the microstructure development of cement paste

Hans-W. Krauss, TU Braunschweig iBMB/MPA

The use of fine inert mineral additions in

conrete – motivation

- Rheology is controlled by small amounts of additives
- Due to the high specific surface a significant impact on hydration kinetics is given (enhanced filler effect)
- In contrast to reactive SCMs inert additions are available worldwide, i.e. limestone, quartz and clay powder
- → Potential for a new, robust and economic method for the control of fresh and hardening concrete's properties

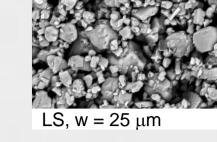


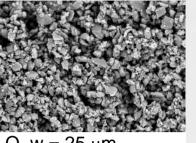
Materials

- Cement: OPC 42,5R (abbrev.: C) Additions: 4 limestone powders (LS), 3 quartz pow. (Q), 3 clay pow. (CL), fly ash (FA), silica fume (SF)
- Paste/mortar mix compositions: f/c = 0 0.20, w/(c+f) = 0.30 - 0.50, no superplasticizer
- Climate conditions: sealed, T = 10 − 40 °C

Methods

- SEM, BET, laser diffraction, zeta potential, sedimentation, water demand, particle packing
- Isothermal calorimetry, non-evaporable water, XRD, thermoanalysis, strength, MIP

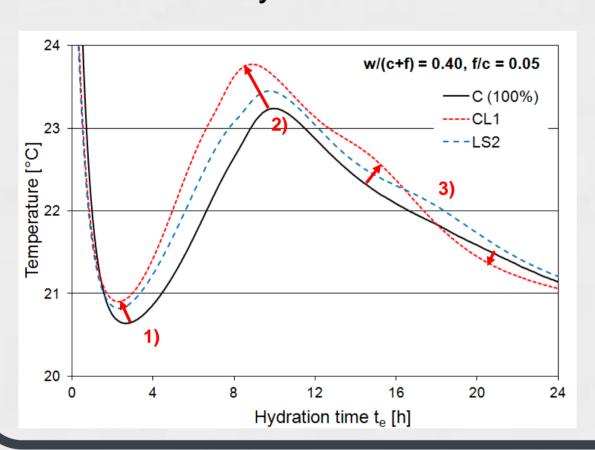






Hydration kinetics – principal findings

- The early age hydration is accelerated (see figure)
- The fineness and the zeta potential are the dominating factors for the hydration kinetics \rightarrow particle agglomeration and allocation in the fresh system \rightarrow nucleation effect (weak agglomeration: Q, FA; strong agglomer.: LS, CL)
- The reacitivity of the additions has no significant impact

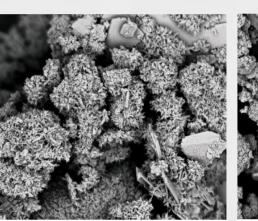


Even small amounts (5%) of fine inert mineral additions lead to:

- 1) An earlier and shorter induction period
- 2) A stronger acceleration of hydration at very early age
- 3) Pronounced secondary peak (followed by a stronger deceleration)

Microstructure development

- The pore size distribution is altered by fine inert additions → lower medium capillary pore size (see figure)
 - → more homogeneous microstructure
- The specific CH amount of the total hydration product volume is not significantly altered
- Cement paste and mortar strength are determined by the "effective" w/c ratio and the substitution rate
- The "gel/space ratio" concept (Powers) is valid for strength prediction



C (100%), 8h, $w = 25 \mu m$

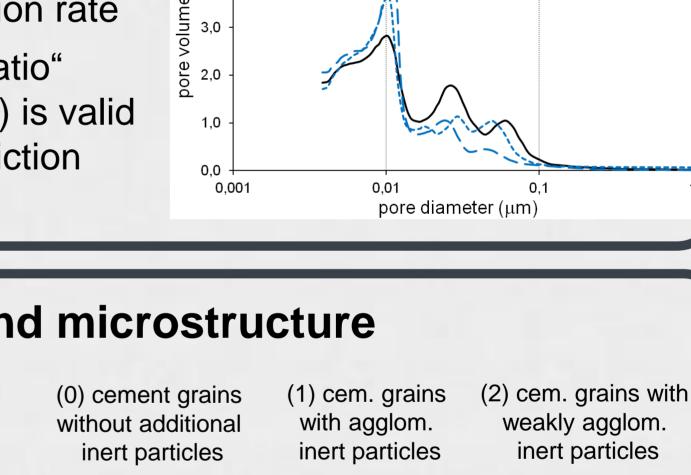


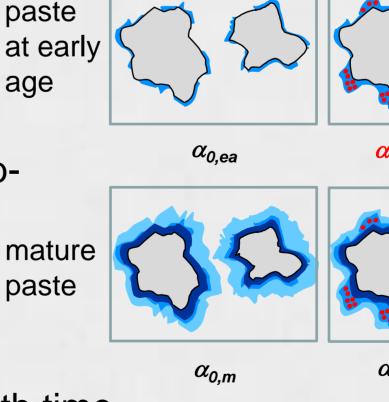
LS (10%), 8h, $w = 25 \mu m$

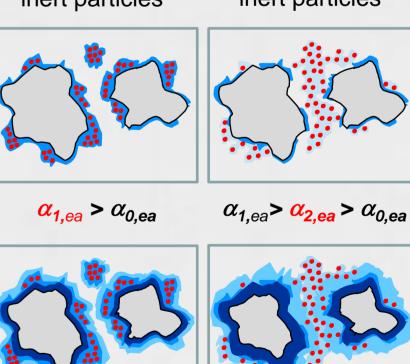
w/(c+f) = 0.40, 28d—— C (100%) **----**LS2, f/c = 0.05 **--** LS2, f/c = 0.10

Model for the impact of the inert particles on hydration kinetics and microstructure

- The agglomeration behaviour and the allocation of the particles/agglomerates in the fresh paste depend on the fineness and the zeta potential of the particles
- Particles with low zeta potential are strongly agglomerated (→ low effective specific area) but at the same time they are suitable as nucleation sites substrates for the precipitation of hydration products \rightarrow high acceleration effect (1)
- Particles with high zeta potential are weakly agglomerated (→ higher effective surface area) but at the same time they are unsuitable as nucleation sites or substrates for the precipitation of hydration products \rightarrow low acceleration effect (2)
- Particles located close to the cement grain surfaces cause a stronger acceleration and a denser hydration product layer at the cement surface (2)
 - → hindered ion diffusion and thus slower subsequent cement hydration
 - > higher hydration degree at early age, with the difference becoming smaller with time
 - → mature paste with increased porosity / heterogeneity (see figure, system (2) compared to systems (0) and (1))







 $\alpha_{0,m} \geq \alpha_{1,m}$



Conclusions and outlook

- Cement hydration kinetics can be controlled by small amounts of inert or reactive mineral additions, the main parameters being the surface charge (zeta potential) and the fineness
- The combined effect on microstructure and hydration kinetics is explained by the model
- The prediction of the zeta potential and the effective specific surface considering the particle agglomeration is very challenging due to the strong influence of the pore solution













Nano-engineering and Characterization of Cement-Based Materials and Development and Testing of CBMs and Structures

Sharali Malik, Staff Scientist, Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany.

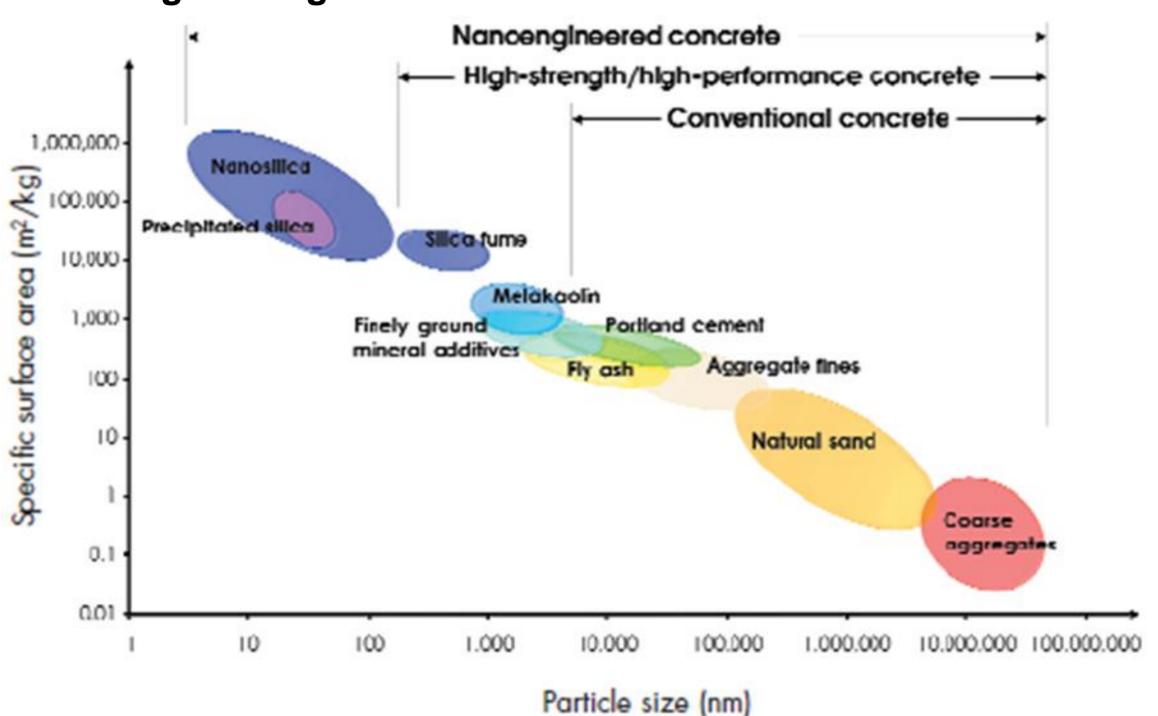
sharali.malik@kit.edu

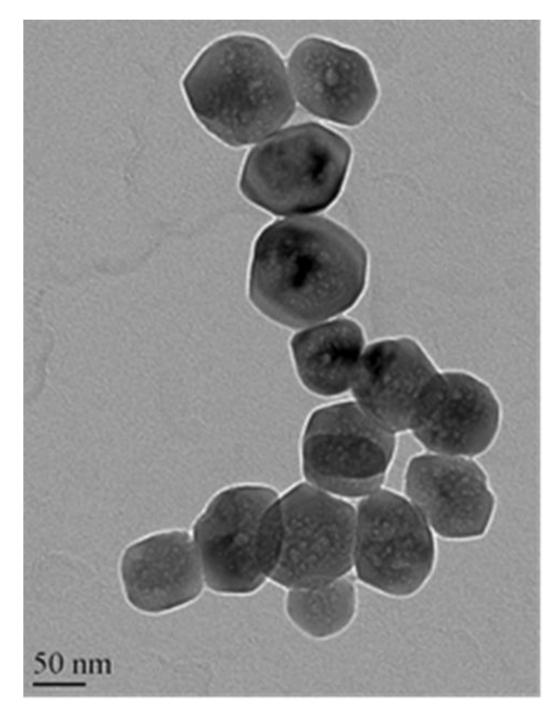
Felicite M. Ruddock, Senior Lecturer, School of Built Environment, Liverpool John Moores University Liverpool, UK. F.M.Ruddock@ljmu.ac.uk

Abstract

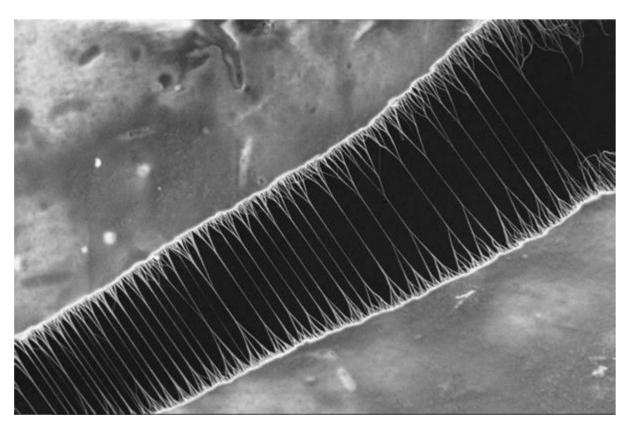
COST Action TU1404 – Towards The Next Generation of Standards For Service Life Of Cement-Based Materials And Structures is an ideal opportunity for the Institute of Nanotechnology (INT) at Karlsruhe Institute of Technology (KIT) in Germany and the School of the Built Environment at Liverpool John Moores University (LJMU) in the UK, together with COST Action TU1404, to develop new concepts and products. This will be accomplished via COST networking activities such as meetings, workshops, conferences, training schools, short-term scientific missions (STSMs) and dissemination activities.

Nano-engineering of cement materials





TEM of Nano-Fe₂O₃ synthesised at INT-KIT.¹



SEM of CNTs fabricated at INT-KIT bridging a micro-crack.²

Nano-engineering, or nanomodification, of cement is a quickly emerging field. Synthesis and assembly of materials in the nanometer scale range offer the possibility for the development of new cement additives such as novel superplasticizers, nanoparticles, or nanoreinforcements. Nano-Fe₂O₃ has been found to provide concrete with self-sensing capabilities as well as to improve its compressive and flexural strengths

Carbon nanotubes/nanofibers (CNTs/CNFs) are potential candidates for use as nanoreinforcements in cement-based materials. Their electrical properties have been used for Traffic Flow Monitoring which is critical for traffic management and operation.

Research at LJMU's School of the Built Environment includes a **Concrete Laboratory** which is equipped for testing wet and hardened concrete using destructive and non-destructive testing methods. This laboratory is also equipped for generalised work on construction and highway materials.³

References

- 1. Malik S., Hewitt I. J., Powell A. K. . EPJ Web of Conferences, 75, 05005, 2014.
- 2. Malik S., Rösner H., Hennrich F., Böttcher A., Kappes M. M., Beck T., Auhorn M. Phys. Chem. Chem. Phys. 2004, 6, 3540.
- 3. Al-Hdabi A., Al Nageim H., Ruddock F. M., Seton L. Journal of Materials in Civil Engineering, 2014, 26, 3, 536.





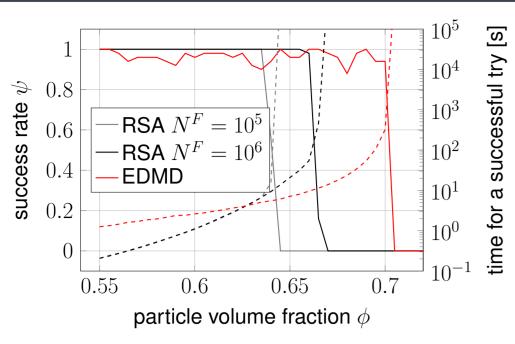




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Generation of mesoscale geometries for concrete using EDMD



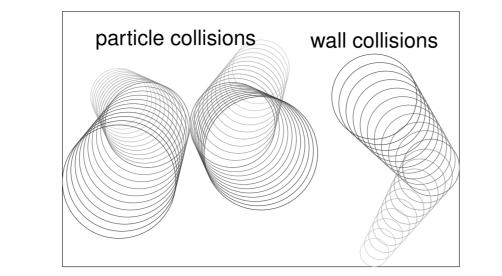
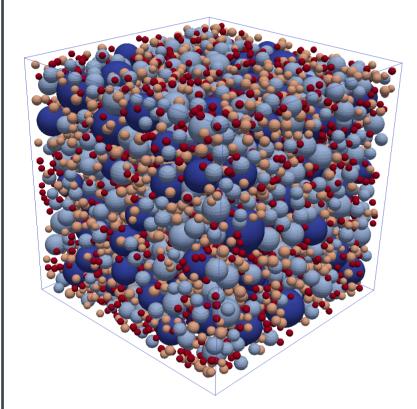
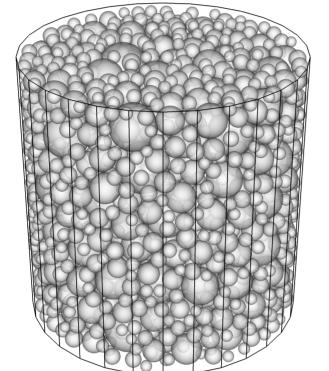


Fig. 1: Maximum particle fraction and computational effort using RSA and EDMD for a box size a = $5 d_{\rm max}$.

Fig. 2: Event-driven molecular dynamics (EDMD) simulation with moving, growing and colliding particles.

- > Grading curve or concrete is simulated numerically by spheres
- > Placement of particles either by Random Sequential Add (RSA) or by Event-Driven Molecular Dynamics (EDMD)
- Advantages of EDMD
- 1. Higher particle fractions
- 2. Better FE-meshes due to increased minimal distance between particles





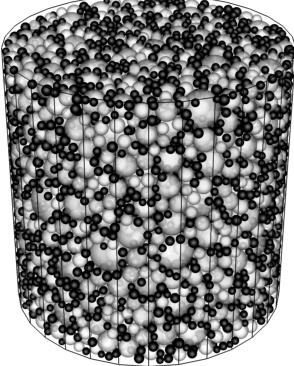


Fig. 3: Mesoscale geometry of a cubic specimen (a=80mm) with a maximum particle size $d_{max} = 8$ mm.

Fig. 4: Cylindrical specimens with 7363 particles, ϕ = 0.7. RSA stopped after 2475 particles. Black particles represent the additional volume fraction that can be added using EDMD.

Modeling of contact in a Split Hopkinson Pressure Bar (SHPB)

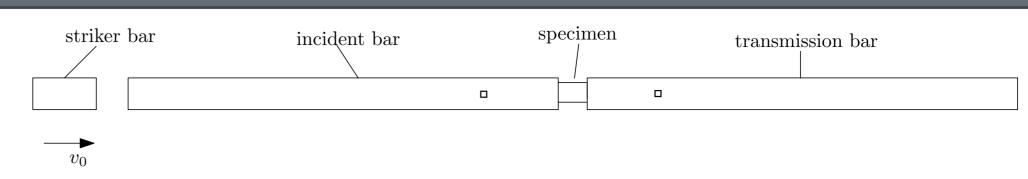


Fig. 9: Setup of a Split Hopkinson pressure bar experiment for the determination of material properties under high strain rates.

- > Simulation of impact with standard contact formulations can lead to artificial numerical oscillations
- Rate dependent material models are sensitive to this oscillations
- 1. Reformulate the equation of motion with constraints into explicit equation

$$\ddot{u} = M^{-1}Ku + M^{-1}M^{1/2}B^{+}GM^{-1}Ku$$

 $B := GM^{-1/2}$

- 2. Regularize the instantaneous change of velocity by a smooth function
- 3. Use a higher order time integration scheme for the explicit equation in combination with spectral elements for the spatial discretization

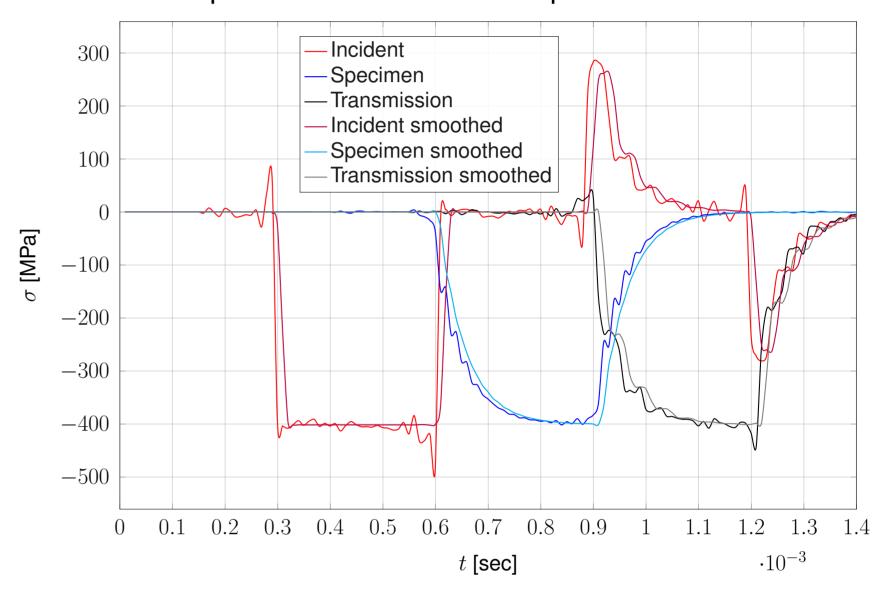
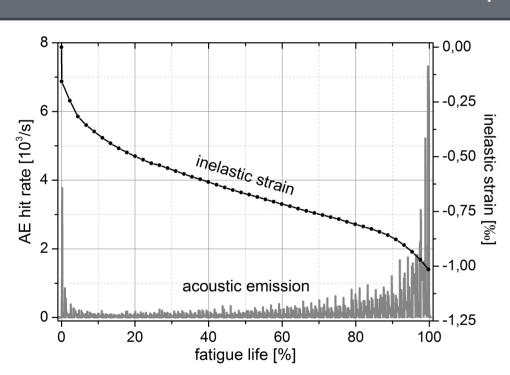


Fig. 10: Comparison of the stress evolution in a SHPB-test for smoothed and standard contact models.

Constitutive concrete model for compression including creep and fatigue



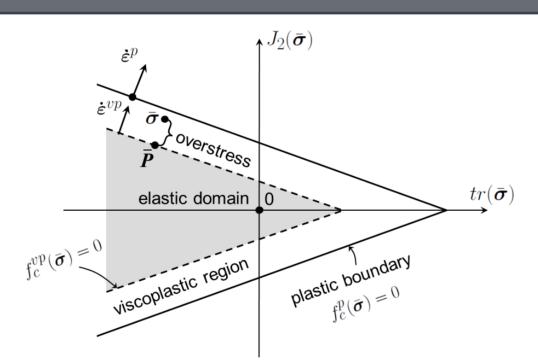


Fig. 5: Acoustic emissions and inelastic strains during a fatigue test under compression.

Fig. 6: Multisurface (visco-)plastic Drucker-Prager model in the effective stress space.

- > Creep and fatigue are simulated with the same model using viscoplasticity combined with damage
- > Evolution of viscoplastic strains

$$\dot{\boldsymbol{\varepsilon}}^{vp} = \dot{\lambda}^{vp} \boldsymbol{C}^{-1} : (\bar{\boldsymbol{\sigma}} - \bar{\boldsymbol{P}})$$

$$\dot{\lambda}^{vp} = \frac{1}{\eta} \left(\frac{\bar{\sigma}_v}{f_c}\right)^n$$

evolution of damage

-20

-40

-60

-120

-140

-160

17.2 MPa

stress [MPa]

$$\dot{\omega} = (1-\omega)\left(\frac{\delta v}{f_c}\right) \frac{\kappa}{\epsilon_\omega}$$

- Fig. 7: Comparison of exp. and numerical results under triaxial compression.
- Fig. 8: Evolution of inelastic strains for creep and fatigue with the same mean load level.

time [s]

V.M. Kindrachuk, M. Thiele and J.F. Unger, Constitutive modeling of creep-fatigue interaction for normal strength concrete under compression. International Journal of Fatigue, accepted for publication

Multiscale modeling using FE^2-X^1

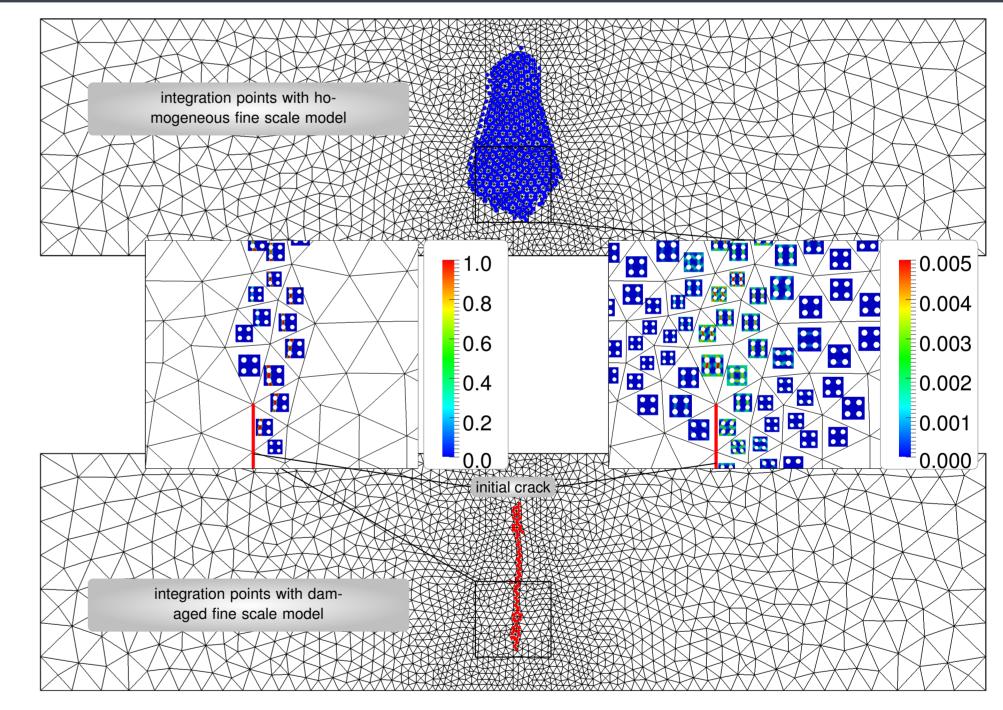
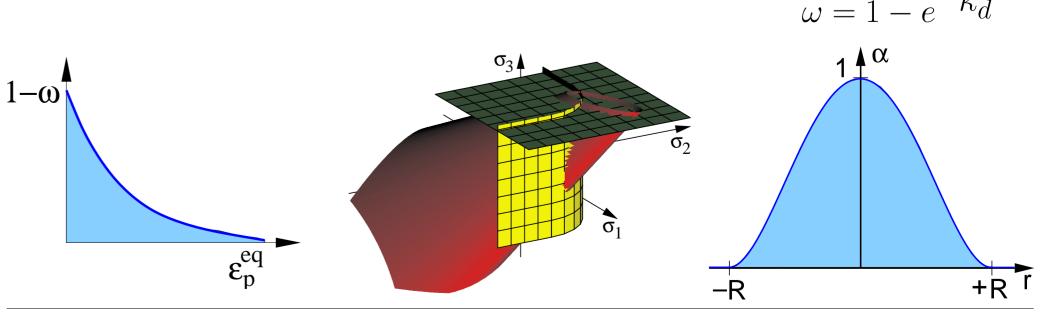


Fig. 11: Three point bending test simulated with the multiscale approach FE²-X¹

- > evolution of stresses
- Combined damage-plasticity $\boldsymbol{\sigma} = (1 - \omega) \boldsymbol{D} \left(\boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}^{\boldsymbol{p}} \right)$ model with Drucker-Prager and
- ▶ Damage evolution driven by nonlocal equivalent plastic strain $\tilde{\kappa}$



Rankine yield surfaces

J.F. Unger, An FE^2-X^1 approach for multiscale localization phenomena. Journal of the Mechanics and Physics of Solids, 61(4):928-948, 2013







Rheology and Early Hydration Equipment





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Dhaalama			
Rheology			
Device	Type of test	Material type	Output
Rheometer 4-SCC	Concrete rheometer	Concrete and mortar	G-Yield [A] and H-Viscosity [As], correspond qualitatively to yield stress and plastic viscosity.
Schleibinger BT2	Concrete rheometer	Concrete and mortar	Yield stress and plastic viscosity related qualitative values
Viskomat NT	Paste and mortar rheometer, cell: paste, fine mortar, coarse mortar, small, medium, large ball cell, Vogel cell	Paste and Mortar	Yield stress and plastic viscosity (Vogel cell) or correlating values.
Anton Paar MCR 501	Fluid and paste rheometer	Fluids to fine mortar	Yield stress/plastic viscosity
EN 12350-2: Slump test	Slump test	Concrete and mortar	Height change
EN 12350-3: Vébé test	Compaction under vibration and load	Concrete and mortar	Time
EN 12350-4: Compactability	Compactability	Concrete and mortar	Height change
EN 12350-5 - Flow table	Flow diameter	Concrete and mortar	Diameter
EN 12350-7: Air content	Pressure vessel test	Concrete and mortar	Air volume
Air void analyser	Fresh concrete drilled out sample, air is released to hydrophobic fluid and a buoyancy balance measures the rising air bubbles vs. the time	Concrete, Mortar, Paste	Air volume and air pore size distribution plus spacing factor
EN 12350-8: Slump flow	Spread diameter	Concrete and mortar	Diameter
EN 12350-9: V-funnel	Funnel efflux time	Concrete and mortar	Time
Efflux funnel flow test (DAfStb)	Efflux funnel plus flow table in one device	Concrete and mortar	Time plus diameter
EN 12350-10: L-Box	Filling ability test	Concrete and mortar	Height difference
EN 12350-11: Sieve segregation resistance	Sieving out of particles larger than 5 mm in fresh concrete	Concrete	Mass difference
Segregation column	Filling of concrete, washing out of coarse components after setting	Concrete and mortar	Mass difference
EN 12350-12: J-ring	Flow test with obstacles	Concrete and mortar	Air volume
Large scale obstacle flow	350 I of concrete are filled into flow box with various obstacles, a	Mortar and concrete (max	Flow behaviour
box (350 I of concrete)	camera on top and from the side observed the flow process. Specimens can be cut after hardening to observe segregation	8 mm)	
Haegermann cone plus table	Flow under lifting and dropping of a plate with a mortar sample. Can also be used for flowable types without lifting and dropping	Paste and mortar	Diameter
Wuerpel-Device	Plastic fresh mortar quare is deformed rhombically. Force and distance can be correlated	Paste and mortar	Force plus deflection
LCPC box	Flow channel	Mortar and concrete	Distance
EN 13395-2: Flow channel	Flow channel	Mortar	Distance and time
Torque controlled Eirich high shear mixer (150l)	Mixing energy observation	Paste, mortar, concrete	Torque

distance can be correlated		
Flow channel	Mortar and concrete	Distance
Flow channel	Mortar	Distance and time
Mixing energy observation	Paste, mortar, concrete	Torque
rly hydration of cementitious syst	em	
Needle penetration	Paste and mortar	Time
Needle penetration	Paste and mortar	Time
Needle penetration	Paste and mortar	Time
Laser measurement od distance of specimen from zero line	Paste, mortar, concrete	Deflection
Isothermal heat flow measurement	Paste and mortar	Energy
Fully adiabatic measurement of the temperature rise.	Paste, mortar, concrete	Temperature
Ultrasound signal runtime	Paste, mortar, concrete	Time
Counting of number of acoustic events	Paste, mortar, concrete	Amplitude, frequency
	Flow channel Mixing energy observation Tly hydration of cementitious syst Needle penetration Needle penetration Needle penetration Laser measurement od distance of specimen from zero line Isothermal heat flow measurement Fully adiabatic measurement of the temperature rise. Ultrasound signal runtime	Flow channel Mortar Mixing energy observation Paste, mortar, concrete Ty hydration of cementitious system Needle penetration Paste and mortar Fully adiabatic measurement of the temperature rise. Paste, mortar, concrete Ultrasound signal runtime Paste, mortar, concrete

Supplementary investigations related to rheology/setting							
In-situ XRD	XRD	powder/paste	Intensity				
Dynamic light scatter	DLS	nm to µm	Hydrodynamic radii of				
device Zetasizer nano ZS			polymers/particle size of				
			particles down to 0.8 nm				
Zeta potential , Zeta sizer	Electrophoresis	nm to µm	Zeta potential				
nano ZS							
Helos Sympatec Particle	Laser diffraction	μm to mm	Particle size distribution				
size and shape analysis							
80 I Pemat mixer with		Paste, mortar, concrete	Water content in mix				
humidity control							
Mixers from 30 ml to	Various mixing principles	Paste, mortar, concrete					
500 l, various principles							







































Activities and projects related to Rheology

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Motivations and competences

Materials | Rheology | Early hydration | Interactions of components



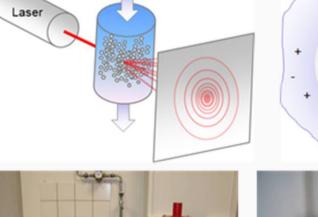


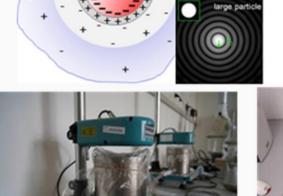












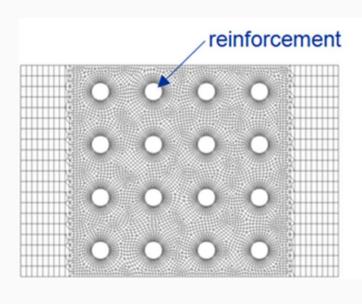
Sternschicht

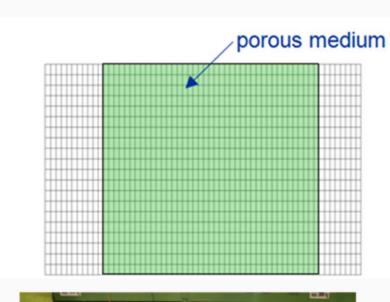


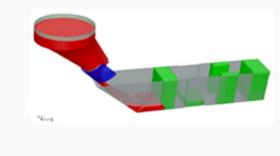
Numeric Simulation of SCC-flow through reinforced sections

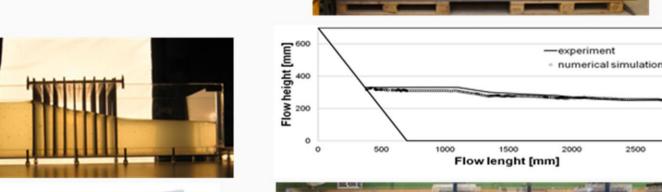
Targets:

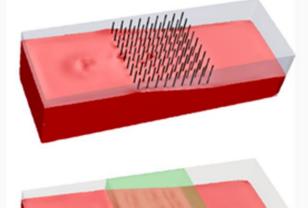
New model that saves time and computational effort Validation by large scale concrete casting experiments

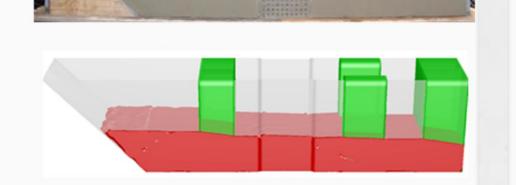










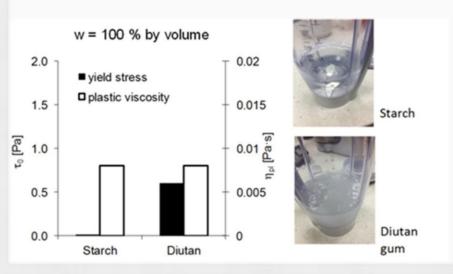


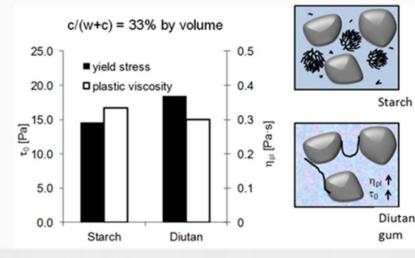
Interactions between PCE and polysaccharides

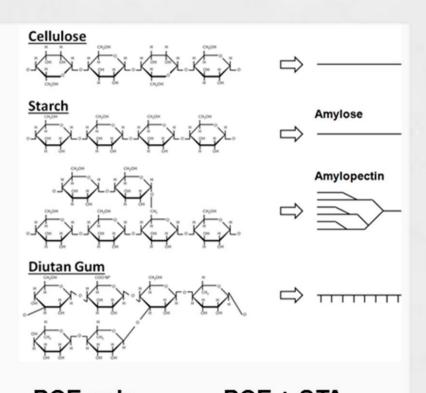
Background: Combined use of different admixture groups

Problem: Uncontrolled rheological phenomena

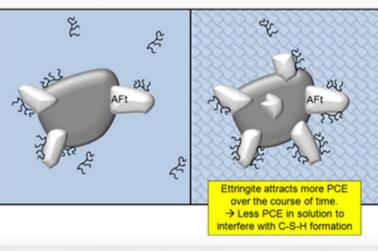
Target: Fundamental understanding of key parameters







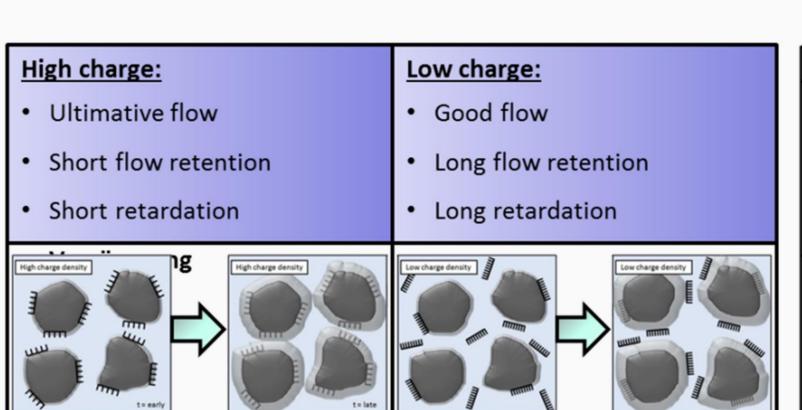
PCE only PCE + STA

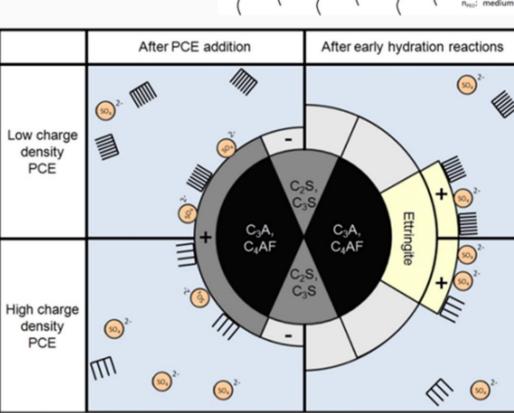


Influence of PCE molecules on rheology

Problem: PCE interactions/incompatibilities with cement/binders

Target: Identification of how to tailor rheology based on PCE





Robustness improvement of SCC

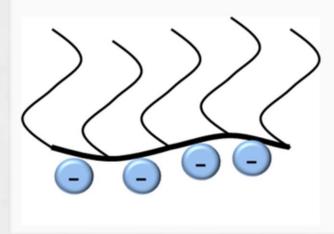
Understanding of interactions between polymers **Target:** and hydrating system.

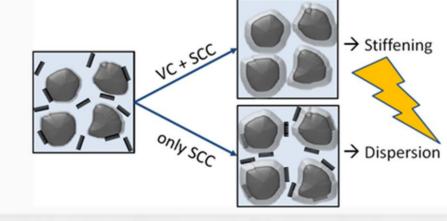
Methods

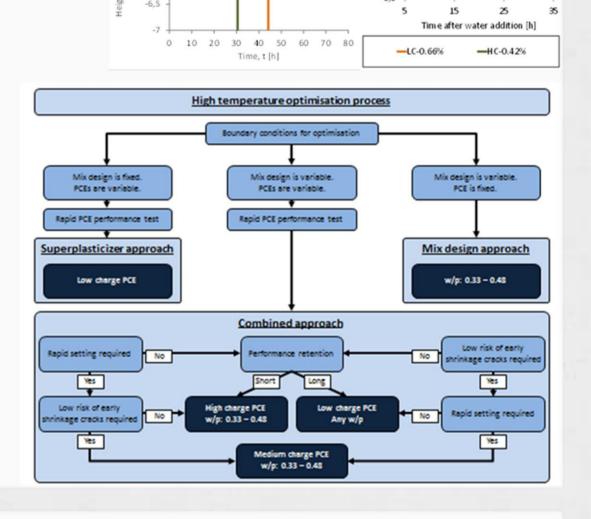
- Rheometry
- Calorimetry

In situ XRD

- Setting
- Shrinkage







SCC dry pre-mixed compound for sub-Saharan Africa

Target: Improve framework for casting of fresh concrete under challenging boundary conditions

399 80
80
972
[% of cem.]
1.96%
0.75%
0.004%





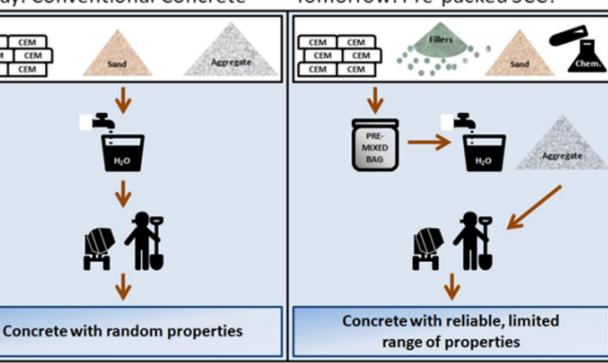
Slump flow:













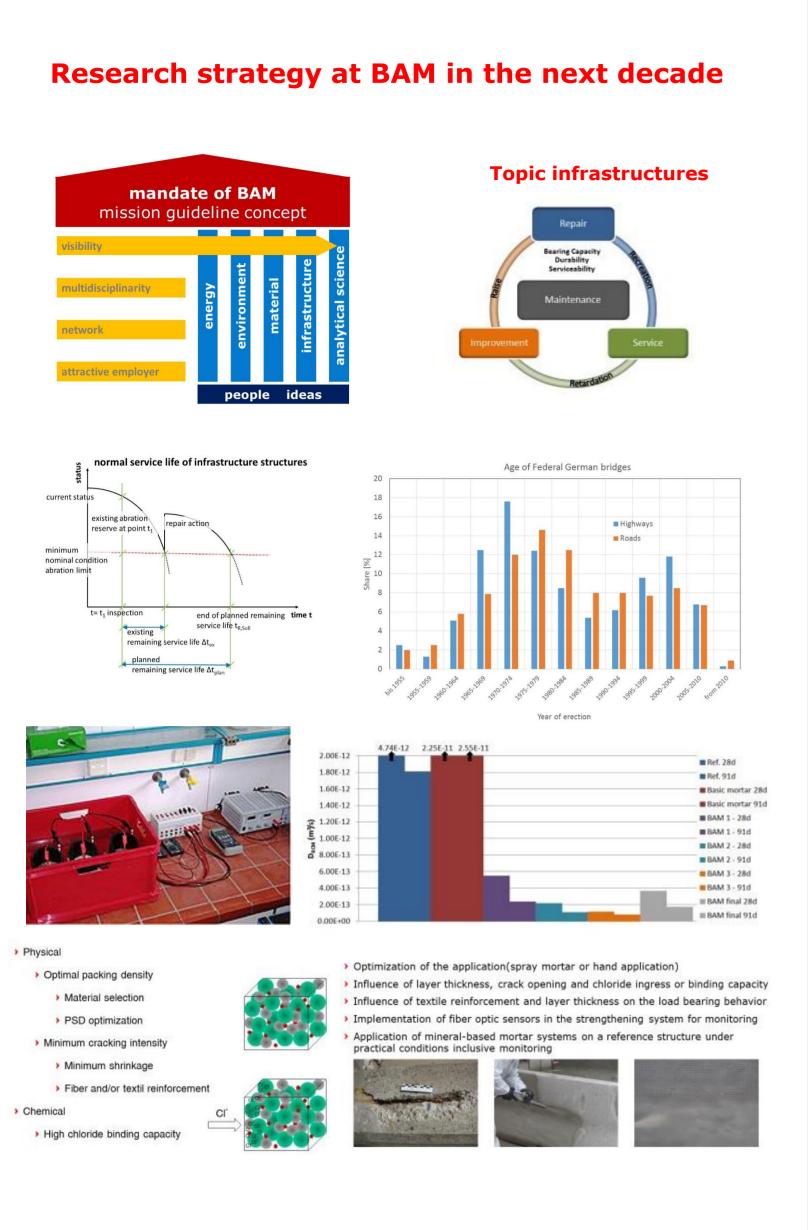


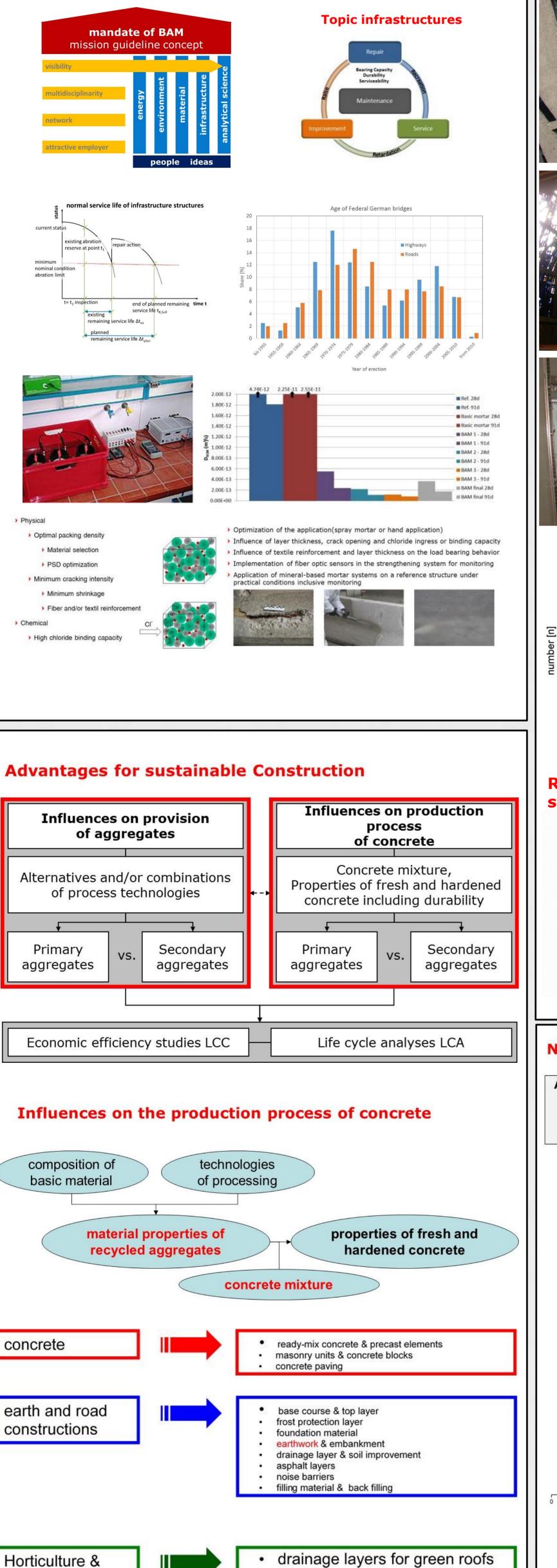


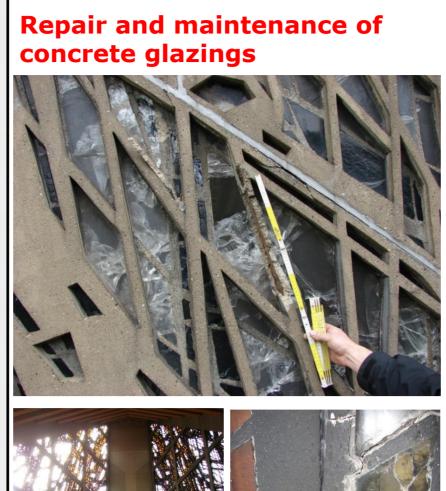
Activities and projects durabily and repair

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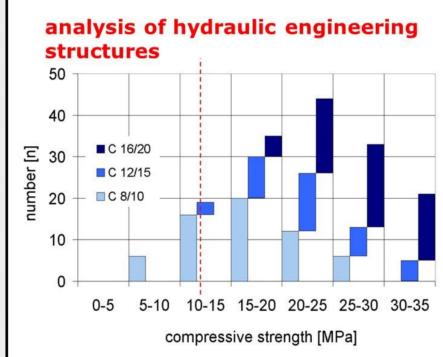






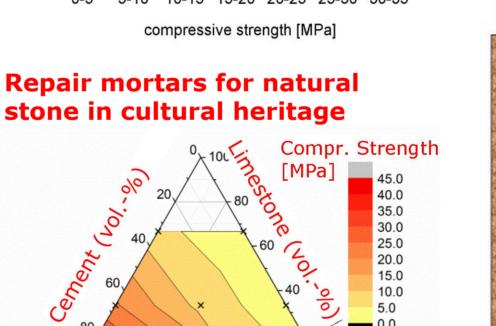




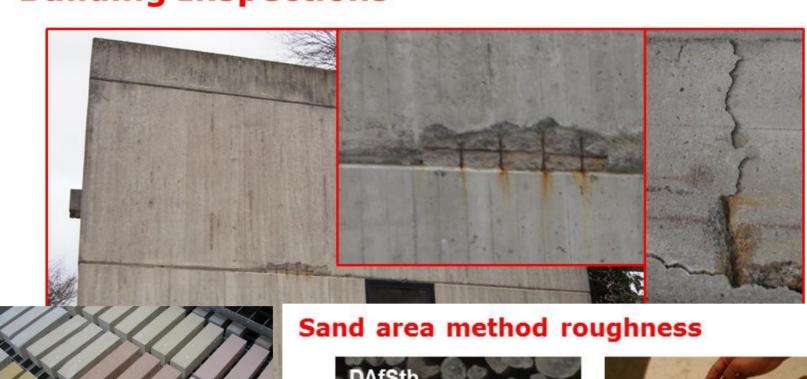


40

60 Hydaulic lime (vol.-%)

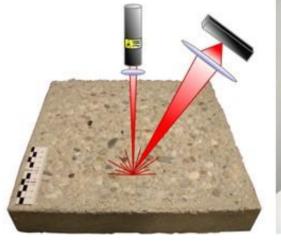


Building Inspections











stress at the interface concrete-shotcrete

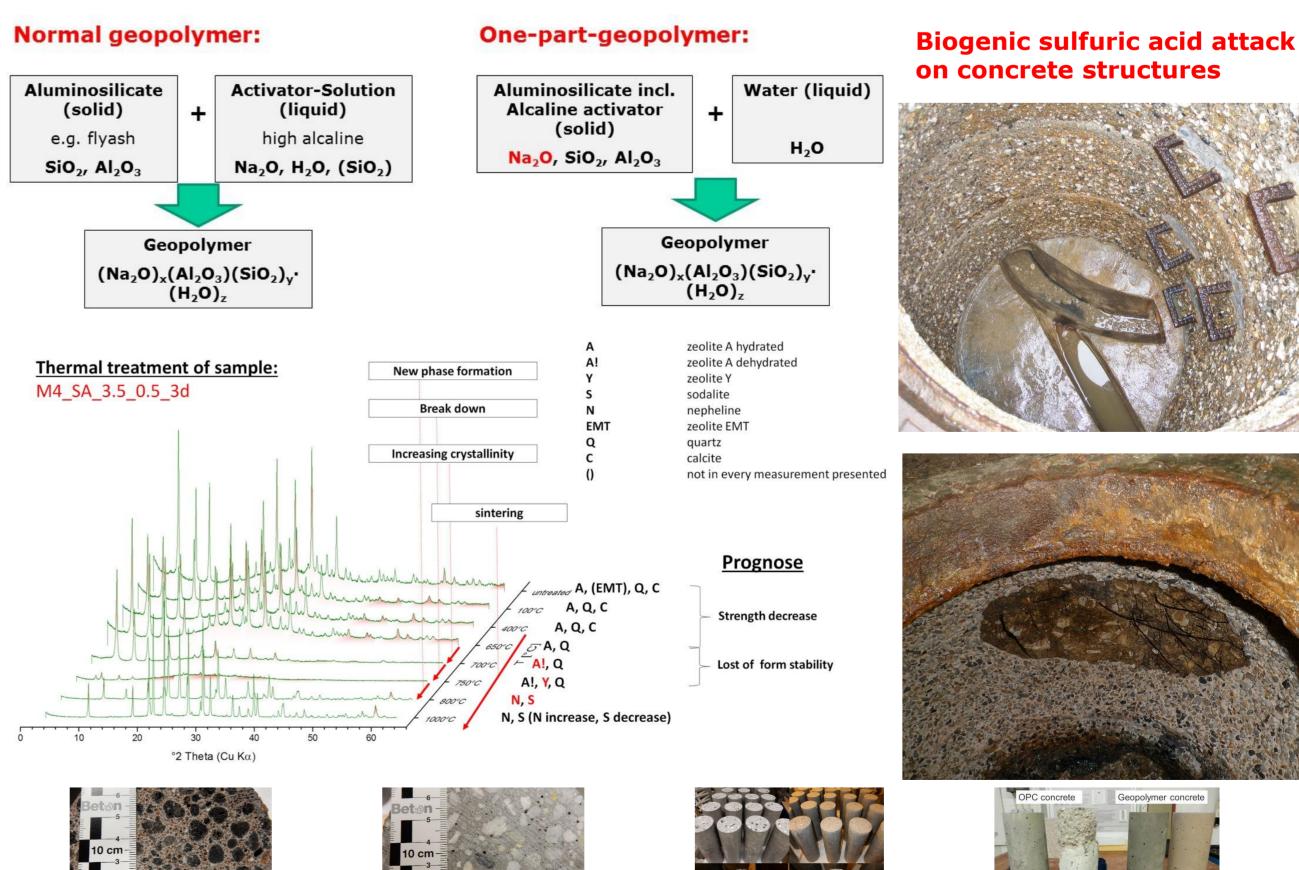
thermal expansion moisture expansion

shrinkage of fresh shotcrete

compressive stress at the interface

- thermal contraction
- drying contraction
- water filled voids at the interface

tensile stress at the interface





scenery

construction

vegetation layer

planting substrates sports field construction









FreshCon and Data Analysis (Fitting)

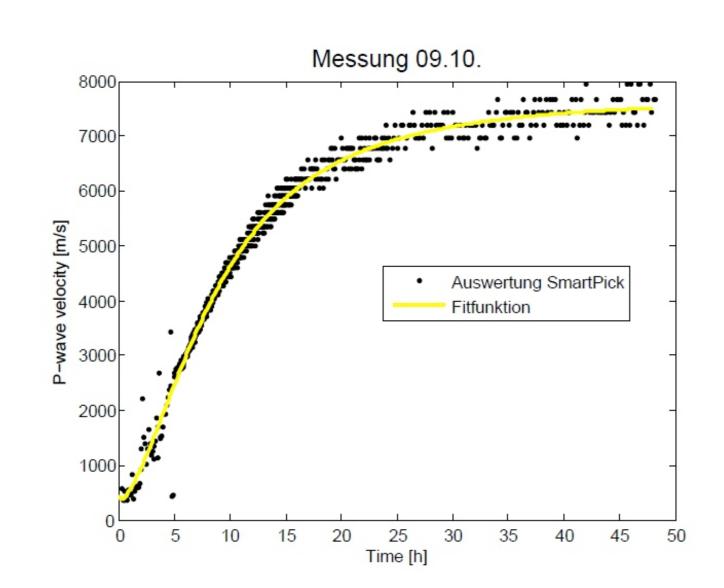
Prof. C. Große, M. Müller, J.Ranz

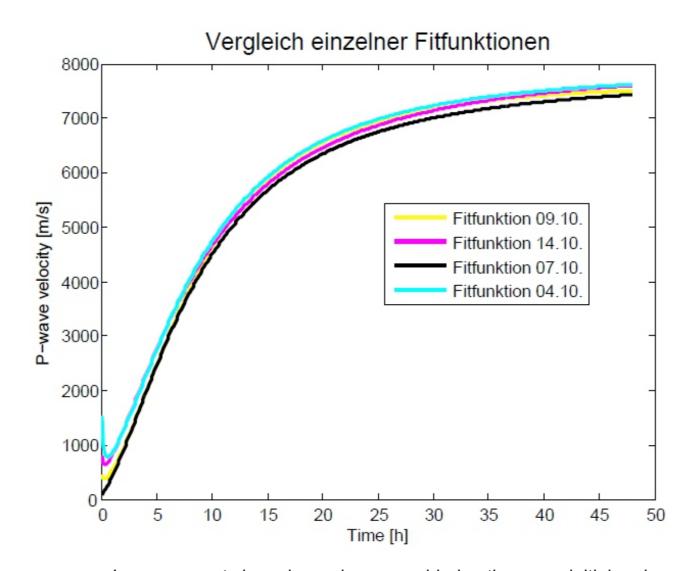
Technische Universität München, Lehrstuhl für Zerstörungsfreie Prüfung Technical University of Munich, Chair of Non-destructive Testing

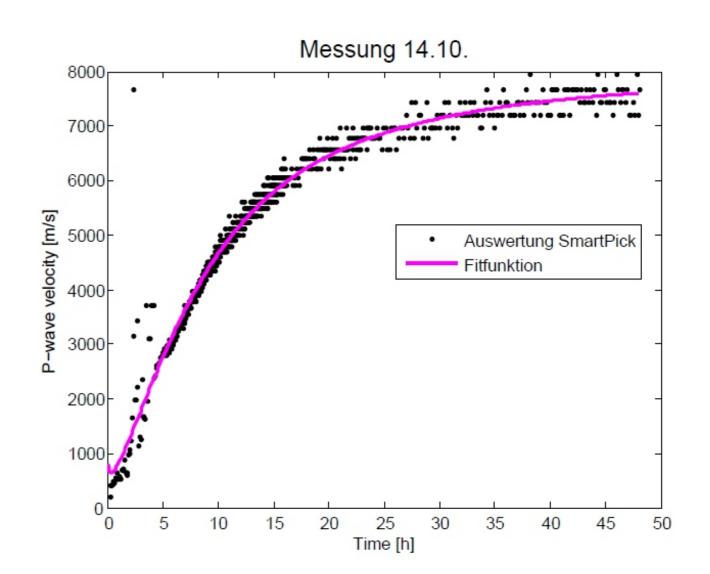
Last Measurements

P-wave velocity, S-wave velocity, E-Module, Poisson ratio was not calculated the right way. Recalculations need to be done.

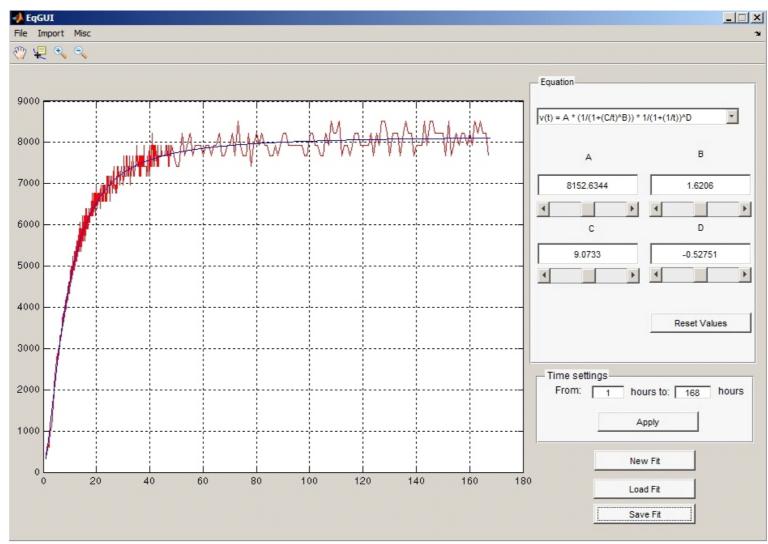
Fitting Purpose was of prime importance.



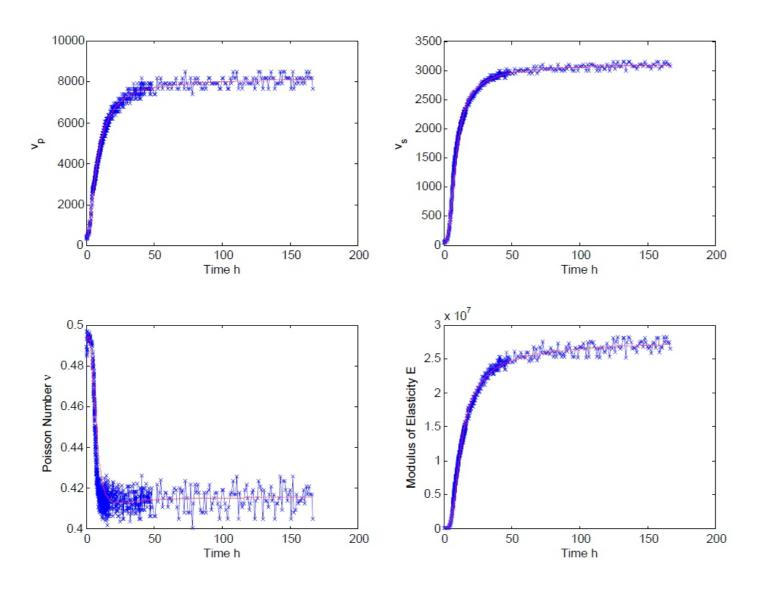




4 measuremets have been done, considering the same initial and boundary conditions each time.



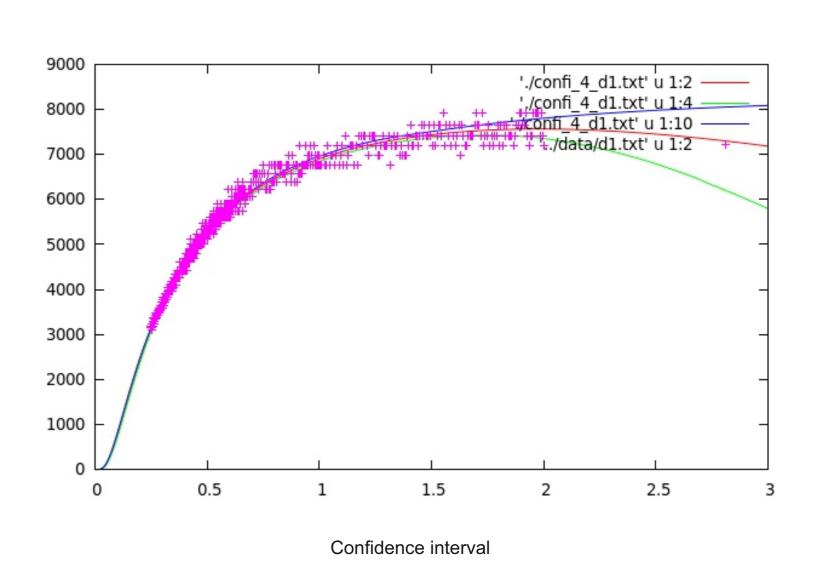
MatLab file for data fitting.



$$v = \frac{\frac{1}{2}v_p^2 - v_s^2}{v_p^2 - v_s^2}$$

Function of Poisson ratio [nu(h)] has been calculated by using each single measurement.

$$E = v_p^2 * \rho \frac{(1+\nu)(1-2\nu)}{(1-\nu)}$$
 nu(h) = (a+b)/2 + (b-a)/pi * arctan(c*h-d)



BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS

Leader in technical higher education

HYDRATION PROCESS OF SCM CONTAINING CEMENT PASTE SAMPLES IN DIFFERENT ENVIRONMENTAL CONDITIONS

TITLE OF PHD PROJECT: INFLUENCE OF SUPPLEMENTARY MATERIALS ON CHEMICAL RESISTANCE OF CONCRETE Katalin Kopecskó (Assoc. Prof., Supervisor) – Lilla Mlinárik (PhD student)

AIMS OF RESEARCH

- Understanding the mechanisms of hydration of SCMs containing cement paste in corrosive circumstances;
- Examine the long-term effect of organic (acetic acid, pH=3) and mineral (sulfuric acid, pH=1) acidic circumstances;
- Analyze and compare the effects of different dosage and ratio of SCMs;
- Long-term curing and investigations (> 360 days).

METHODS

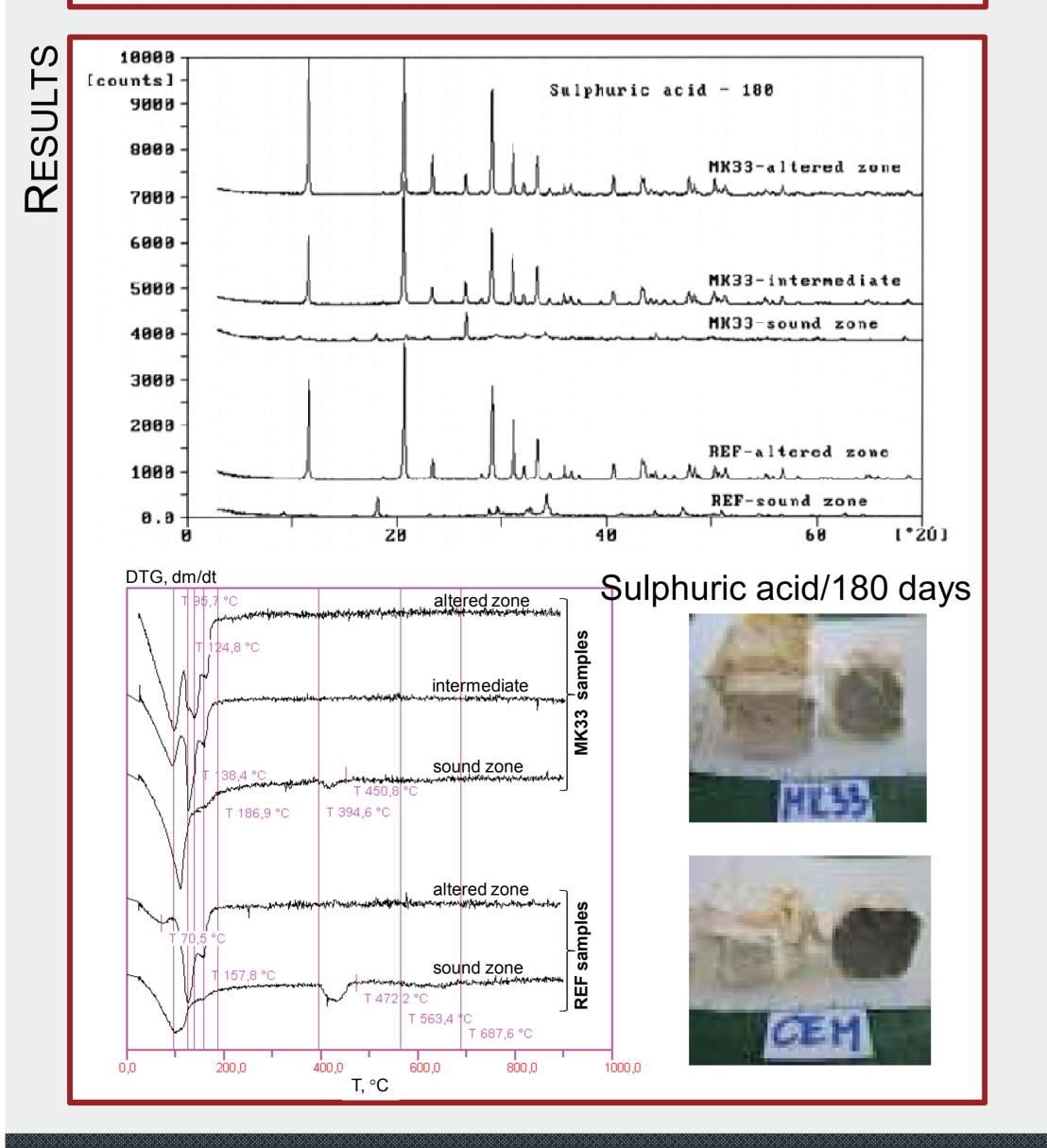
- Thermal analyses TG/DTG/DTA
- X-ray powder diffraction XRD
- Compressive strength UCS

MATERIALS

- CEM I 42.5 N
- Metakaolin (MK)
- Silica fume (SF)

EXPERIMENTAL PROGRAM

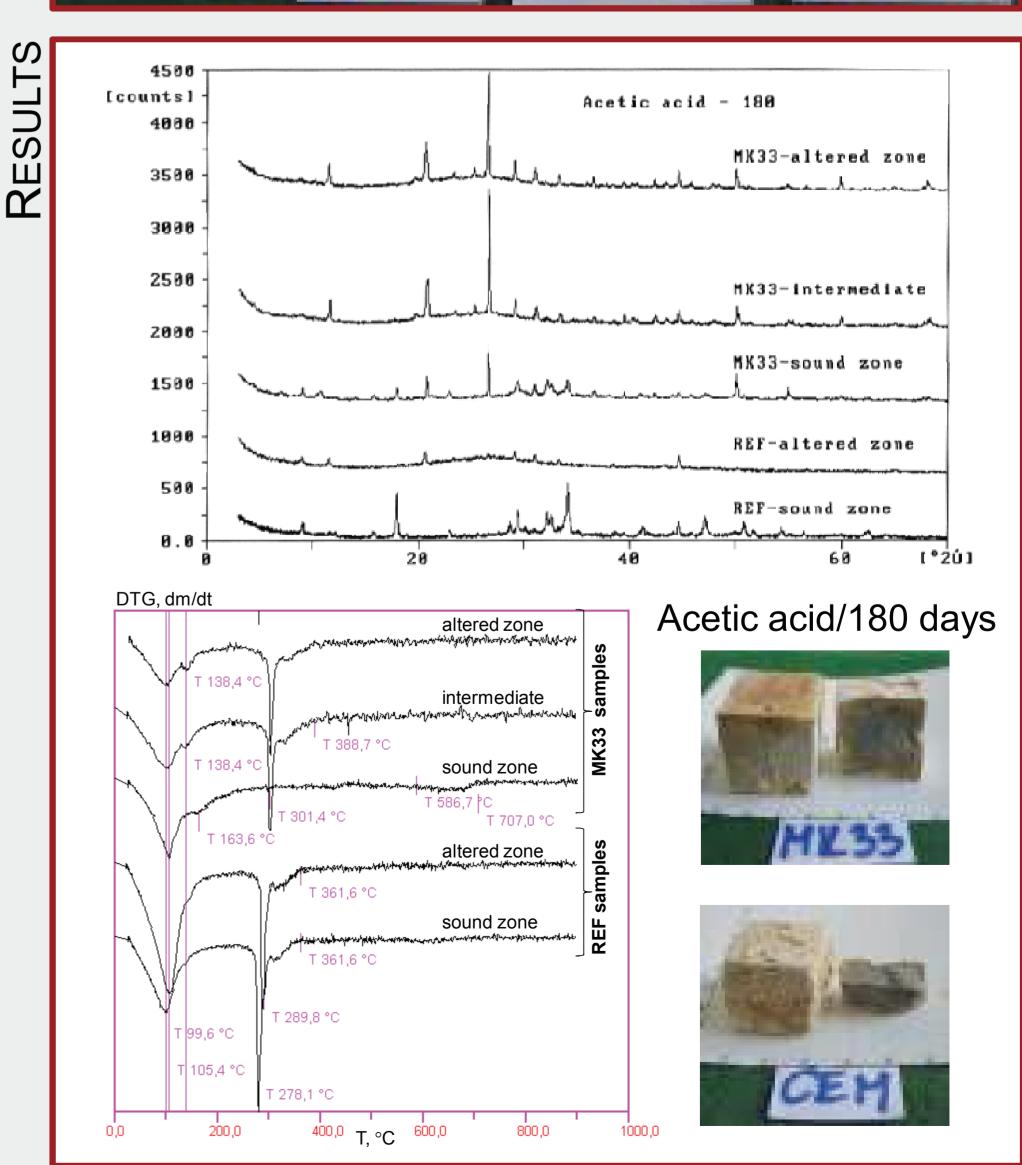
- Specimens: 30x30x30 mm cement paste cubes;
- Testing time: 1, 7, 14, 28, 90, 180, 360, ? days;
- Curing conditions (from 7th days):
 - climate chamber (20±1°C, RH=65%),
 - water $(20\pm1^{\circ}C)$,
- from 28 days
 - organic acidic solution (acetic acid, pH=3),
 - mineral acidic solution (sulphuric acid, pH=1);



COMPOSITION OF SAMPLES

Mix	CEM142.5 N m/m%	Metakaolin m/m%	Silica fume m/m%	MK + SF m/m%
1	100	-	_	
2	83	17	-	
3	75	25	-	
4	67	33	-	
5	95	-	5	
6	90	-	10	
7	85	-	15	
8	83	12	5	12+5=17
9	75	17	8	17+8=25
10	67	25	8	25+8=33













BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS

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SCM IMPACT ON FRESH AND MECHANICAL PROPERTIES OF SELF-COMPACTING CONCRETE

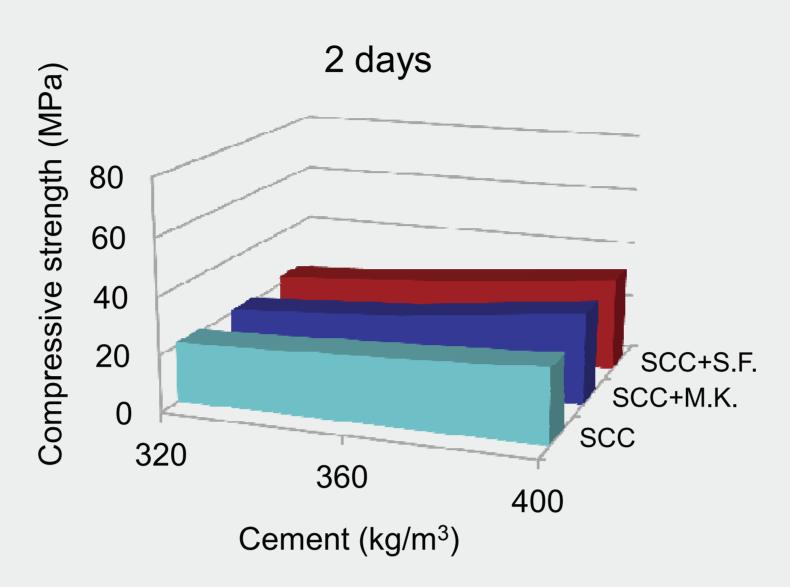
TITLE OF THE PHD PROJECT: POROSITY OF SELF-COMPACTING CONCRETE Dr. Salem Georges Nehme (Assoc. Prof., Supervisor) – Abdulkader El Mir (PhD student), Hungary Dept. of Construction Materials and Technologies

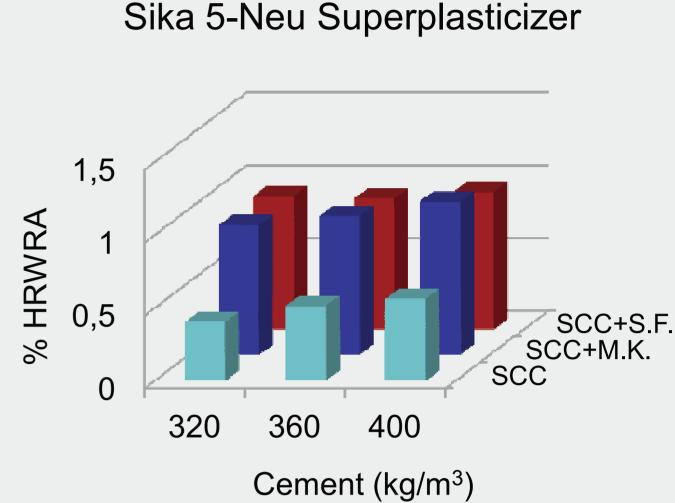
AIMS OF THE RESEARCH

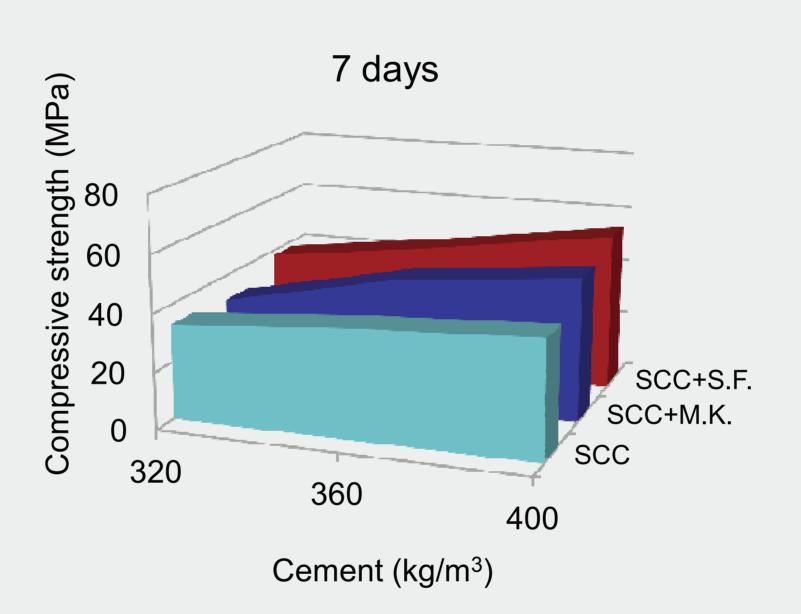
- Efficiency evaluation of SCMs
 (Metakaolin and Silica Fume) on
 the durability indicators of self compacting concrete (SCC)
- Influence of Metakaolin (MK) or Silica Fume (SF) on the consistency (Sika 5-Neu) and hydration process (CEM III/A 32.5 R-MSR) with respect to early compressive strength of concrete mixtures
- Micro- and mesostructural characterization (total porosity, apparent porosity) with respect to MK and SF
- Surface hardness variation (Schmidt hammer).

RESULTS AND ANALYSIS

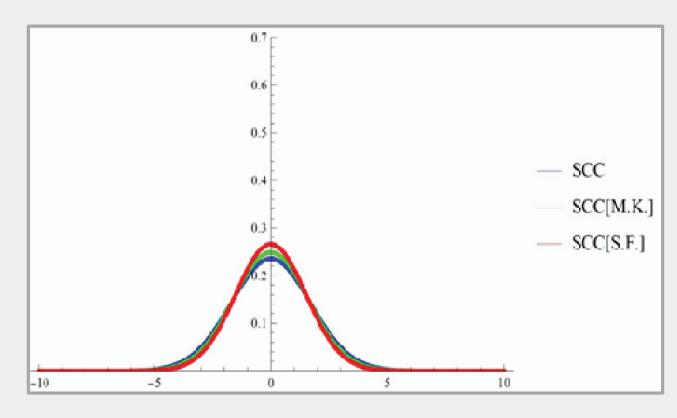
- With the usage of SCM variation of compressive strength is noticed in several periods:
 - 1. A slightly 12% increase at
 2 days with highest dosage
 cement 400 kg/m³
 - 2. An average of 18% increase at 7 days
 - 3. A significant increase of 28% at 28 days.
- A higher reliability in Schmidt hammer with inclusion of SCM
- SCC mixtures in which SCM are applied require higher dosage of HRWRA due to specific surface area
- An average of 25% decrease in capillary pores due to MK and SF.

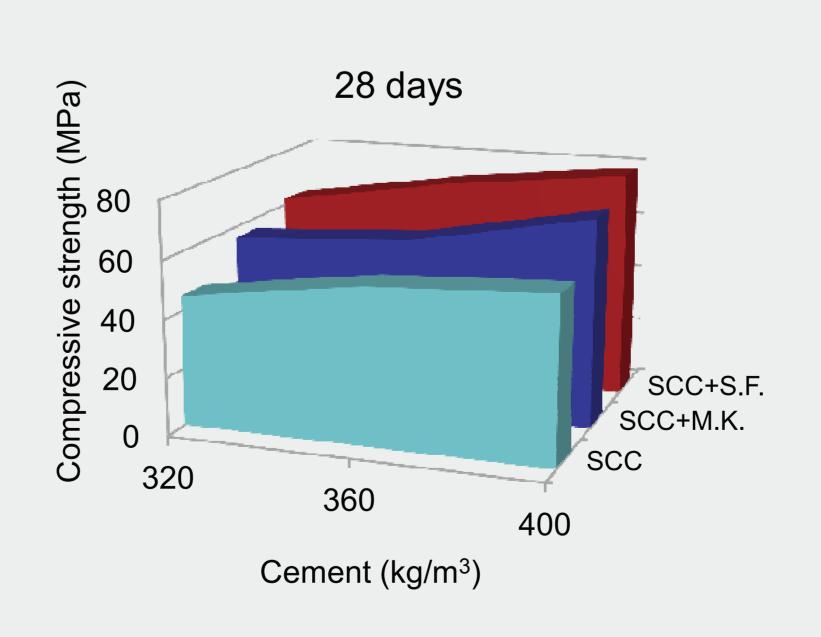


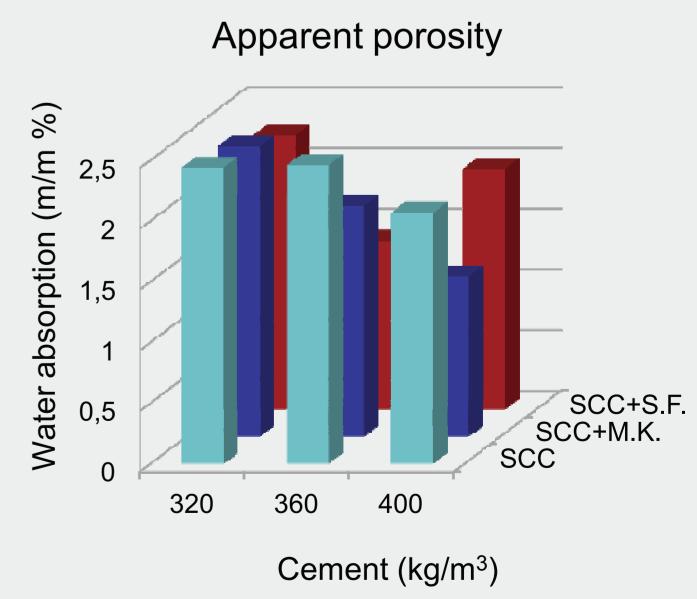




Surface hardness density function

















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EARLY AGE SHRINKAGE CRACKING TENDENCY OF CEMENT BASED MATERIALS

Olivér Fenyvesi PhD ass. Professor, BME, Department of Construction Materials and Technologies, Hungary

Influencing factors of early age shrinkage in concrete mix design [Neville 1995]:

- cement content of the paste
- specific surface area of cement
- fine aggregate content (under 0.125 mm particle size)
- specific surface area of fine aggregate
- water-cement ratio
- total aggregate content
- type of aggregate
- water absorption capacity and water content of aggregate
- applied admixtures
- compacting rate of paste
- porosity
- other added components e.g. fibres.

Shrinkage of NWAC according to cement and water content [Grube, 2003] Shrinkage [‰] 1,4 0,4 9,5 0,6 w/c =1,2 w = 250 kg/m3 Practical 1,0 range - 225 0,8 0,6 w/c = 0.30,4 150 0,2 700 400 500 600 200 300 Cement content [kg/m³]

Relationship between tensile strength and shrinkage induced tensile stress [Neville 1995] Induced Elastic Tensile Stress Creep -Tensile Strength of Concrete Development Stress of Cracking Stress after Creep Relief

References:

Grube H: Definition der verschiedenen Schwindarten – Beton, 2003/12 sz. p. 603 Neville A M: Properties of concrete, ISBN: 0-582-23070-5

Publications of present topic:

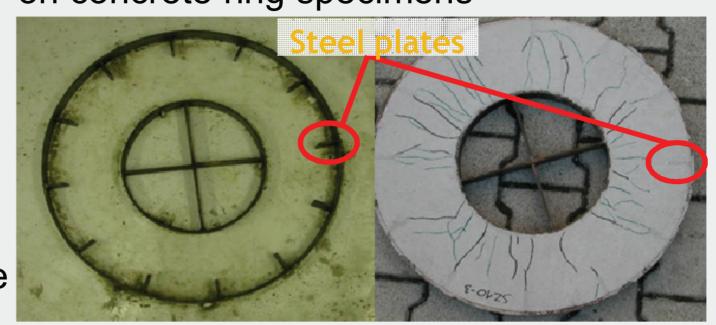
[1] Fenyvesi, O.: "Affect of lightweight aggregate to early age cracking in concrete" in Periodica Polytechnica, vol. 55/1, 2011 pp. 63-71., ISSN: 0553-6626, online ISSN 1587-3773

[2] Józsa, Zs., Fenyvesi, O. " Early age shrinkage cracking of fibre reinforced concrete" in Concrete Structures vol.11, 2010 pp. 61-66., ISSN: 1419-6441

[3] Nemes, R., Fenyvesi, O.: "Early age shrinkage cracking in LWAC" in 6th Central European Congress on Concrete Engineering, CCC2010 (eds. Srumova, Z., Sruma, V.), Marianske Lazne, 30. September – 1. October 2010 PP. 79-88. ISBN: 978-80-87158-26-5

[4] Fenyvesi, O., Szabó, K. Zs., Józsa, Zs. "Swelling-shrinking properties of cement and polymer based adhesives" in 4th Central European Congress on Concrete Engineering, CCC2008 (eds. Radic, J., Bleiziffer, J.), Opatija, 2-3. October 2008 pp. 577-583. ISBN: 978-953-7621-01-8 [5] Kara, P., Borosnyói, A., Fenyvesi, O.: Performance of waste glass powder (WGP) supplementary cementitious material (SCM) Drying shrinkage and early age shrinkage cracking in Építőanyag – Journal of Silicate Based and Composite Materials, Vol. 66, No. 1 (2014), 18–22. p. DOI: http://dx.doi.org/10.14382/epitoanyag-jsbcm.2014.4

Experimental study according to the Austrian fibre-concrete tech. specification (Richtlinie Faserbeton 2002 and 2008) on concrete ring specimens













2011.10.06

-50

-150

-200

-250

-300

[m/mn]

ormation

Def



2011.10.09

2011.10.10

2011.10.08

2011.10.07

Crack formation

Time

2011.10.11











UNIVERSITY of MISKOLC, FACULTY of EARTH SCIENCE & ENGINEERING HUNGARY

Institute of Raw Material Preparation and Environmental Process Engineering



Mechanical activation of cementitious materials

Gábor Mucsi, Ádám Rácz, Zoltán Molnár, Roland Szabó, Barnabás Csőke

Contact: Gábor Mucsi Assoc. Professor, e-mail: ejtmucsi@uni-miskolc.hu. Web: ejt.uni-miskolc.hu

INTRODUCTION

Mucsi G, Rácz Á, Mádai V,

Mechanical activation through ultrafine milling is an effective procedure where an improvement in technological processes can be attained via a combination of several effects, which influence the properties of applied minerals (Balaz et al, 2010). The primary effect of mechanical activation is the comminution of mineral particles, which results in changes in a great number of physicochemical properties of a particular system. During mechanical activation, the crystal structure of a mineral usually becomes disordered and the generation of defects or other metastable forms can be registered (Balaz and Achimovicova, 2006). The aim of the present poster is to represent some research results of the Institute of Raw Material Preparation and Environmental Processing, University of Miskolc, Hungary in the field of mechanical activation of fly ash and portland cement and to show the effect of the mechanical activation on the properties of fly ash based hydraulic and geopolymer binder.

activated cemet

MECHANICAL ACTIVATION OF PORTLAND CEMENT Specific grinding work, W_a [kJ/kg]

SEM images of mechanically

Netzsch MiniCer stirred media mill Volume: 0.2 dm³ Operation mode: continuous/batch wet

STIRRED MEDIA MILLS FOR MECHANICAL ACTIVATION

Effect of the specific grinding work on the produced surface area in case of ball and stirred media milling of portland cement

Effect of the specific grinding work on the relative top intensity of alite and βbelite in case of ball and stirred media milling of portland cement

Specific grinding work, W_a [kJ/kg]

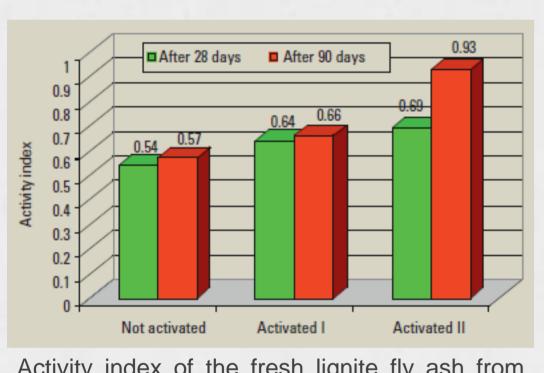
Self-developed vertical disc stirred media mill Volume: 3 dm³



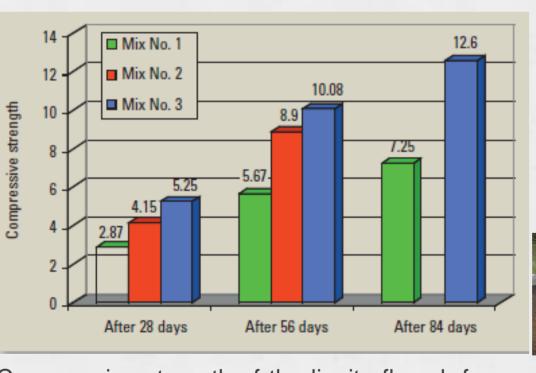
Self-developed horizontal disc stirred media mill Volume: 0.5 dm³ Operation mode: batch and wet/dry

FLY ASH BASED HYDRAULIC BINDER

Mechanical activation of cement in stirred media mill, POWDER TECHNOLOGY 235: pp. 163-172. (2013)

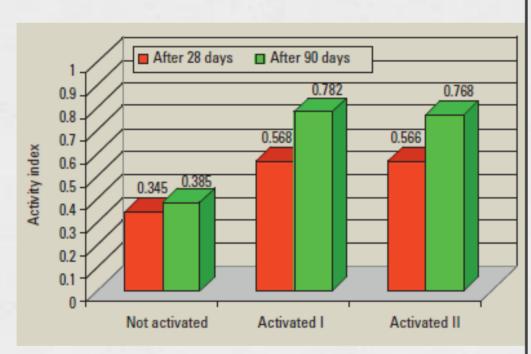


Activity index of the fresh lignite fly ash from Visonta Power Plant before and after mechanical activation

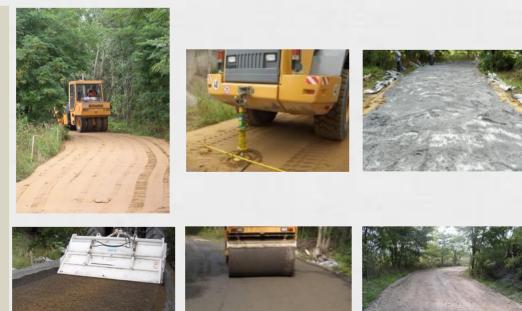


Compressive strength of the lignite fly ash from Gyöngyösvisonta as a function of time (binder content in the concrete - 1: 135 kg/m³, 2: 170 kg/m³ and 3: 205 kg/m³)

as constituents in binders, CEMENT INTERNATIONAL, 4/2009, Vol. 7,



Activity index of the stockpiled brown coal fly ash from Tiszaújváros before and after mechanical activation

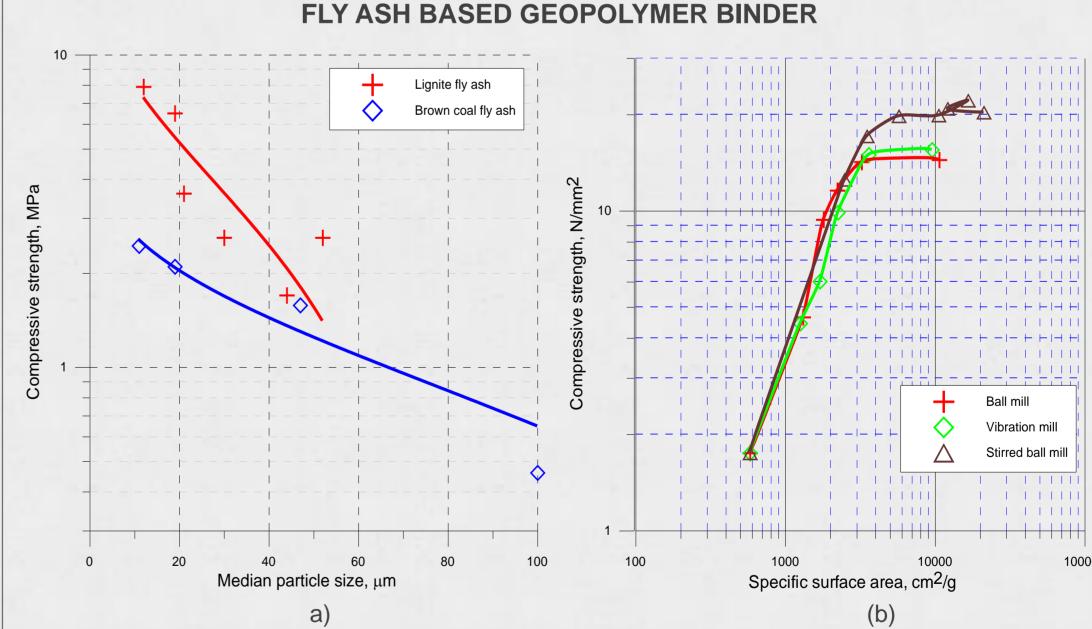


Construction of an experimental road section made of mechanically activated fly ash - lime binder (without PC)

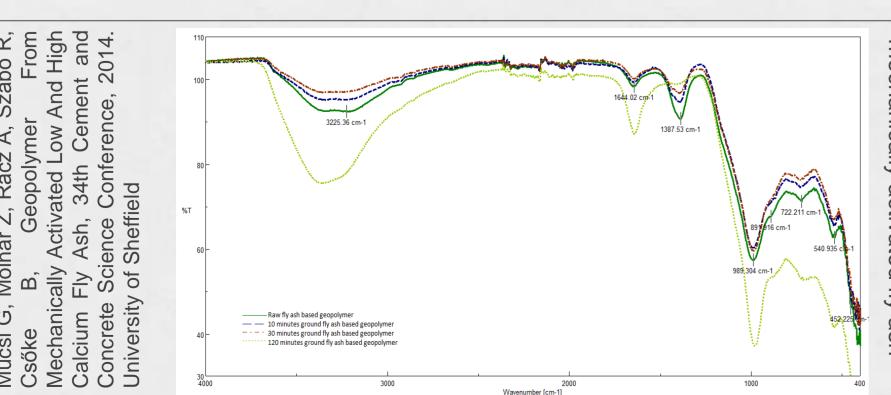
Mucsi G, Csőke B, Gál A, Szabó M, Mechanical activation of lignite fly ash and brown coal fly ash and their use



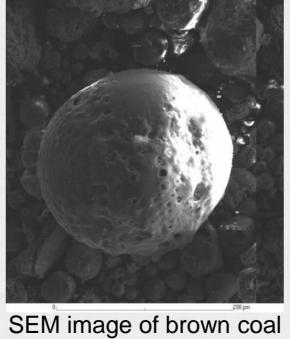
disc stirred media mill Volume: 5 dm³ Operation mode: continuous/batch and dry/wet



Relation between a) characteristic particle size x₅₀ of the mechanically activated fly ash (lignite and brown coal) and b) specific surface area and geopolymer compressive strength (brown coal)



fly ash FTIR mechanically activated spectra based geopolymer brown from coal



raw fly ash

coal from d geopolymer activated fly as — 10 minutes ground fly ash based geopolyn 0 minutes ground fly ash based geopolyme 60 minutes ground fly ash based geopolyme









THCM multiphase modeling of concrete

From early ages issues to prediction of delayed behavior

GIUSEPPE SCIUMÈ

Department of Innovation Engineering - University of Salento giuseppe.sciume@unisalento.it

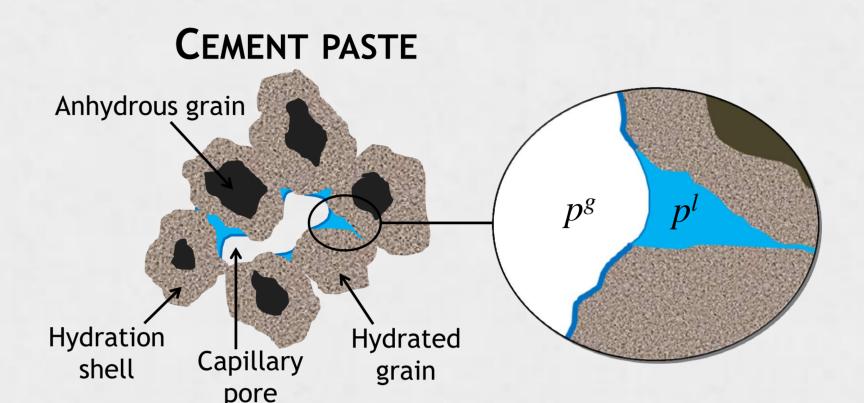
General mathematical model

Concrete is modeled as **porous solid** with pores filled by liquid water and a gaseous mixture of water vapour and dry air (the two gases and their mixture are assumed to behave as ideal gases). Concrete properties (Young's modulus, tensile strength, permeability, etc.) depend on the hydration degree.

PHASES	SPECIES	
	Anhydrous cement: <i>Cs</i>	
Solid <i>s</i>	Aggregates: As	
	Hydrates: <i>Hs</i>	
Liquid <i>l</i>	Liquid water <i>l</i>	
Casconic a	Water vapour: <i>Wg</i>	
Gaseous g	Dry air: <i>Ag</i>	

GOVERNING EQUATIONS

- An Arrhenius eqn for hydration rate
- Enthalpy balance equation
- Mass balance eqs of phases and species, with Powers' model for mass exchanges and reaction terms
- Linear momentum balance eqn of the solid phase



MECHANICAL CONSTITUTIVE MODEL

Mechanical behavior is modeled by an **elastic damage model coupled with creep**, which includes the evolution of mechanical properties with respect to the degree of reaction and damage.

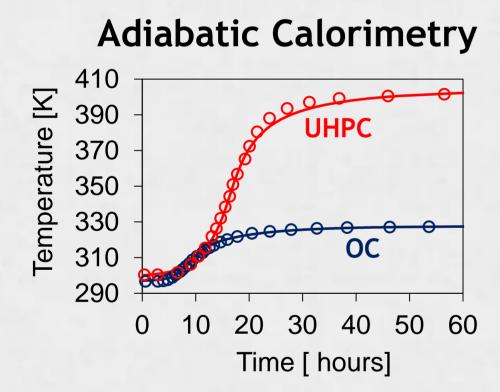
NUMERICAL SOLUTION

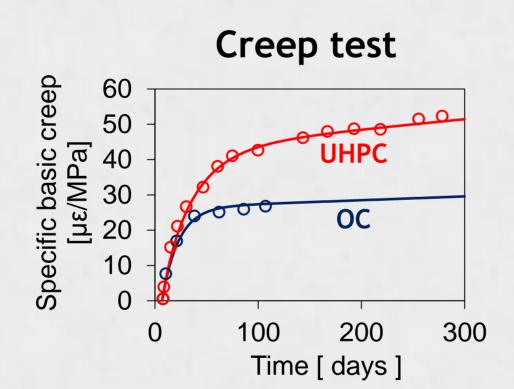
The mathematical model has been implemented in Cast3M (FE code of the CEA, the French Atomic Energy Commission) and solved assuming an unidirectional coupling, THC \rightarrow M.

Modeling of beams repaired with OC and UHPC

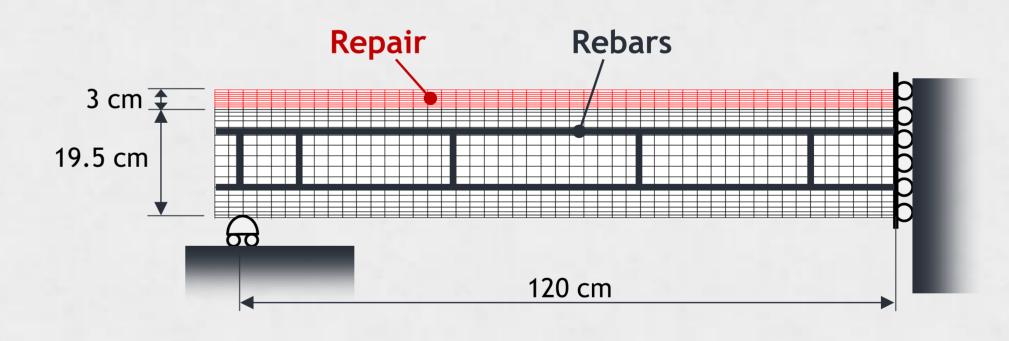
For the experiment (performed by Bastien Masse, 2010), three identical reinforced beams were cast. At thirty days after the casting, two of these beams, after the hydrodemolition of 30 mm of the upper part, had been repaired: one using an **ordinary concrete (OC)** and the other using an **ultra-high performance fiber reinforced concrete (UHPC)**. The third beam is the reference specimen.

IDENTIFICATION OF THE INPUT PARAMETERS

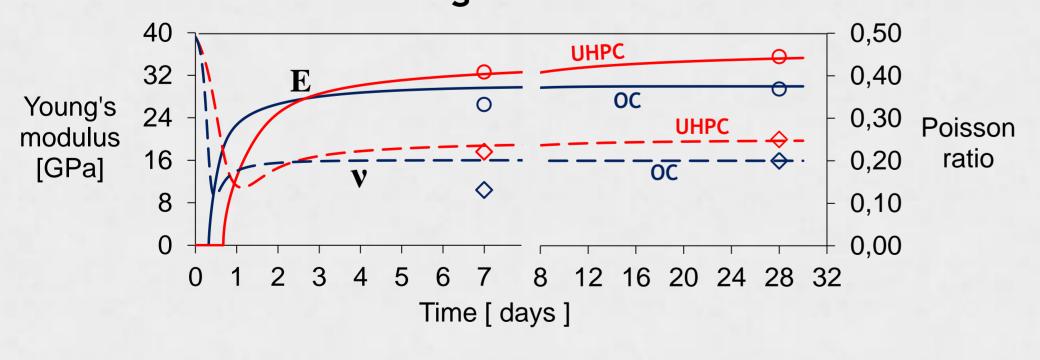




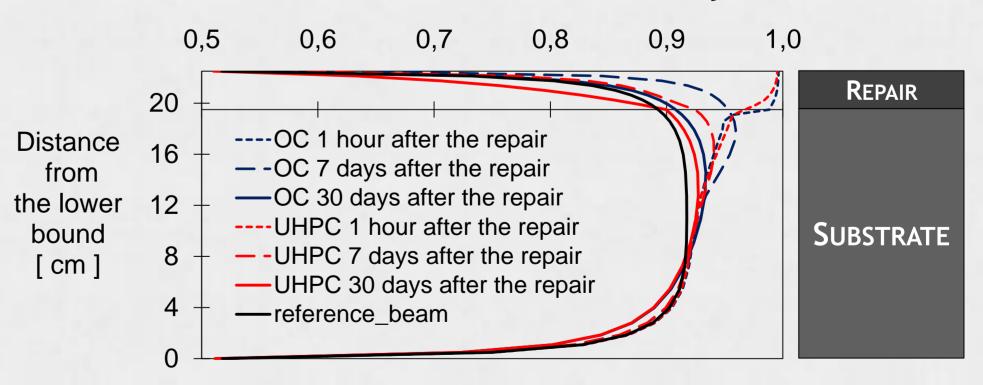
MODELING OF THE THREE BEAMS



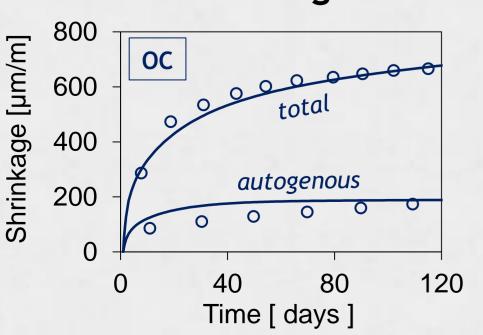
Evolution of the Young's modulus and Poisson's ratio

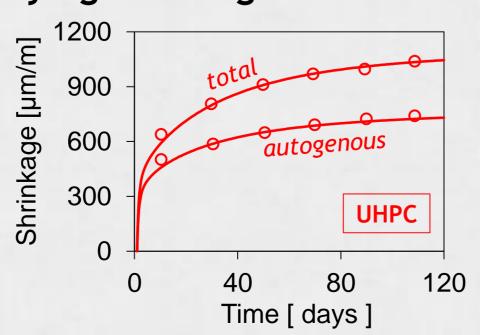


Evolution of relative humidity

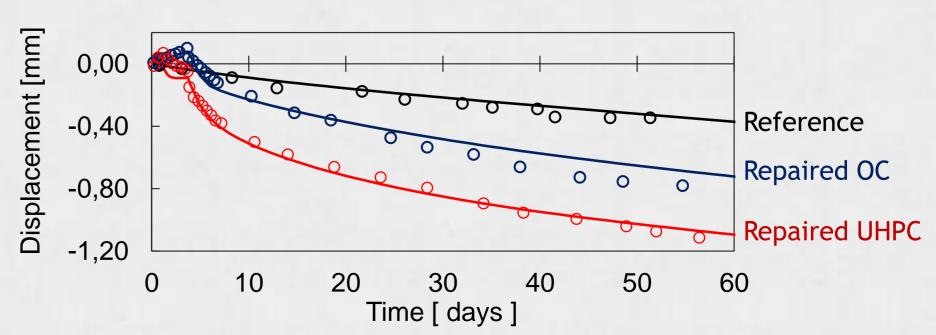


Autogenous and drying shrinkage





Deflection of the three beams













RIGA TECHNICAL UNIVERSITY **FACULTY OF CIVIL ENGINEERING**

TESTING TECHNIQUES USED TO EVALUATE PROPERTIES OF CEMENT BASED MATERIALS AND CONCRETE STRUCTURES

COST action TU 1404

D.Bajare*, A. Korjakins*, G. Shakhmenko*,

* Faculty of Civil Engineering, Riga Technical University, Kalku st. 1, Riga, Latvia

High performance concrete

Early age hydration of cement pastes (w/c 0.20) with Superabsorbent polymers (SAP) and reference pastes without SAP were investigated in cooperation with EMPA (Switzerland) [5].

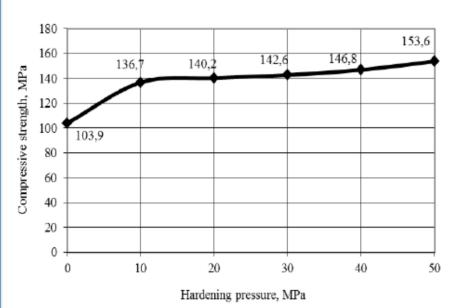


Figure 2. Compressive strength of the UHPC specimens hardened under pressure [6]

Practical study on producing ultra high performance concrete with target strength over 200 MPa and investigation of long-term compressive strength development [7]

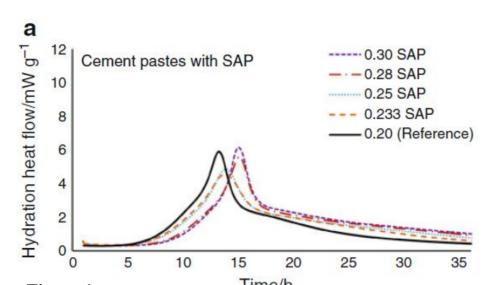


Figure 1. Hydration heat release rate (until 36 h) of cement pastes with SAP [5]

Effect of different pressure application to a fresh ultra high performance concrete (UHPC) right after casting and during the first 24 hours of hardening [6]

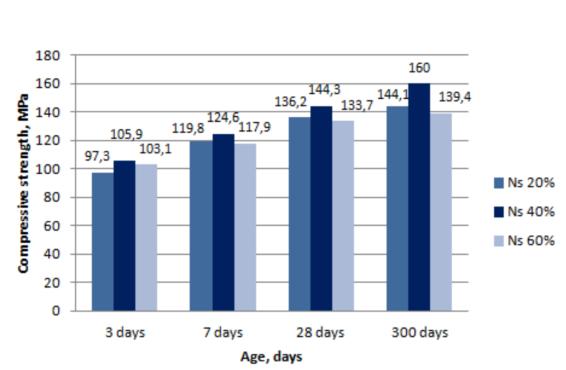


Figure 4. Compressive strength of the specimens with different microsilica/nanosilica ratio at different ages [7]

Thermal treatment/heat resistence of high strength concrete

treatment effect Thermal on concrete compressive strength were investigated. Additional tests were made for water absorption and permeability, including SEM analysis comparing concrete specimens with and without specific thermal treatment [1]

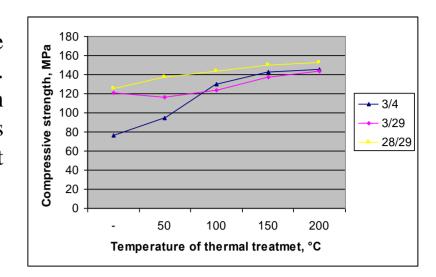
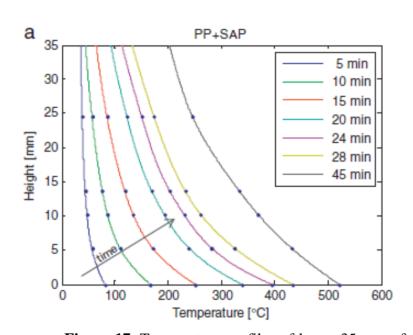


Figure 15. Compressive strength of the speciments [1]

Examples an experimental procedure designed for casting light on the mechanisms behind spalling were proposed and illustrated and valuable input for both numerical approaches and mixture design was provided in cooperation with EMPA (Switzerland) [2]



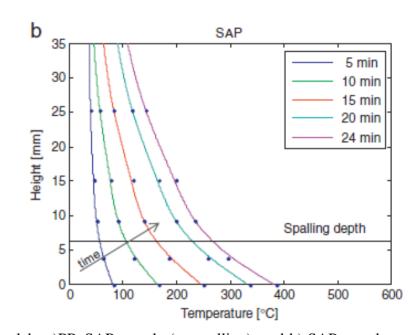
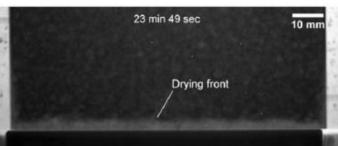
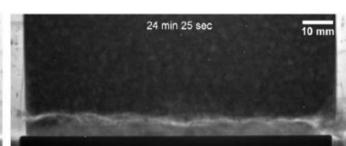


Figure 17. Temperature profiles of lower 35 mm of the mortar slab: a)PP+SAP sample (no spalling), and b) SAP sample (spalling occurred after 24 min at 6 mm height) [2]





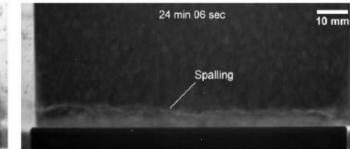


Figure 16. Sequence of raw neutron radiographs (cropped bottom part of the sample) showing drying and spalling in SAP mortar. Time 23:49: just before spalling, the dried region is visible in brighter gray values. Time 24:06:the spalling crack appears first as a fine line and widens in the successive radiographs. The gray levels refer to beam intensity [2]

Replacement of cement, using pozzolanic additives

Usage of biomass ash in the conventional concrete 1) as microfiller to increase density of specimens and 2) as replacement of Portland cement to decreased amount of binder for same strength concrete [11]

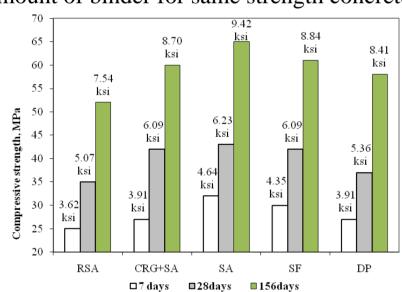


Figure 6. Concrete mixtures with ground ashes and standart microfillers compressive strength results. RSA – samples with reed straw ash; CRG+SA - samples with canary reed and straw ash; **SA** – samples with straw ash; SF - samples with silica fume; DP - samples with dolomite powder [11]

Heavy concrete

Determination of alternatives to microsilica and evaluation of pozzolanic additives performance in normal and high-strength concrete [10]

Evaluation of the economic benefit and efficiency for the partial replacement of cement with coal combustion bottom ash (CCBA), as well as possibility to use CCBA as microfiller with pozzolanic properties in production of concrete [12]

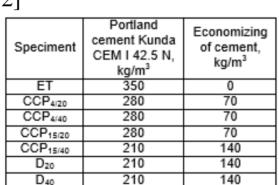


Figure 8. Economizing of cement replacing it with CCBA [12]

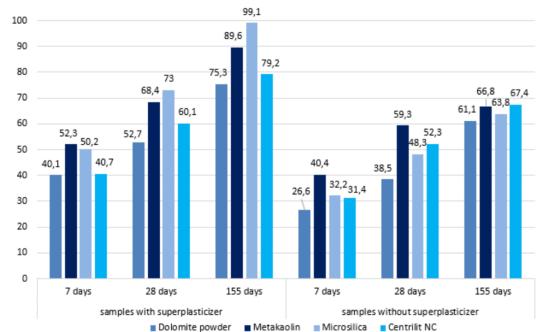


Figure 9. Compressive strength of the samples with /without superplasticizer [10]

Concrete sawing waste recycling as microfiller in concrete production

The recycling of the sawing waste/sludge in 100,0 production of the new concrete - evaluation of 90,0 dust-water suspension as micro filler in selfcompacting concrete [3]

SCC mixes with cement content 360 kg/m3; **SF-1** mix, containing silica fume as a microfiller; **SL-1** mix, containing only concrete sludge as micro filler; **D** mix, containing dolomite powder.

SCC mixes with cement content 450 kg/m3; **SF-2** mix, containing silica fume as a microfiller; **SL-2** mix, containing only concrete sludge as micro filler; 50/50 mix, where silica fume is was dispersed in water-sludge

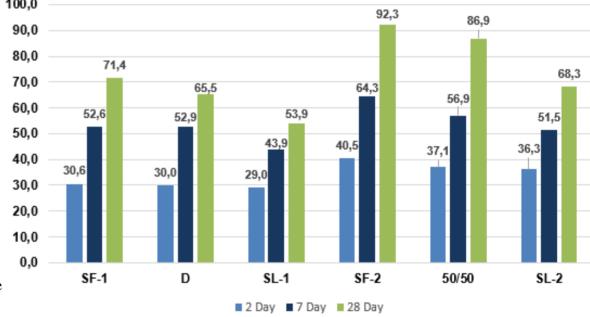


Figure 19. Compressive strength results [3]

Dolomite waste as microfiller in concrete production

Evaluation of mechanical and physical properties of expanded clay lightweight concrete, comparing it with samples of the concrete containing different amount of dolomite waste[4]

S1 and **S2**– traditional compositions with quartz sand; **D1** and **D2** – samples with dolomite sand;

KM, KR3 and KRM - high strength lightweight concrete with expanded clay, which contains dolomite and traditional quartz sands varying from 0 till 100%.

 $\mathbf{D1}$ KM KR3 KRM 1506 1534 1589 1643 Density, kg/m³ 2006 1970 1935 Compression strength after 7 17.0 17.5 53.9 45.9 24.8 21.9 53.4 days, MPa Compression strength after 19.4 19.7 25.6 61.3 24.3 66.1 61.1 28 days, MPa Tension strength after 28 2.04 1.60 1.73 2.17 days, MPa Water penetration, mm 35 29 16 25 Content of expanded clay, % 38.8 38.8 32.6 32.6 21.0 21.4 21.8 **Figure 21.** Hardened concrete properties [4]

Analysis of several kinds of metal waste such as iron and steel powders, mill scales, steel punching,

metal shavings and other iron-containing waste from mechanical engineering and metallurgy industries, and the possibility of their use in the manufacturing of concrete products like highly dispersed metallic fillers [8, 9]

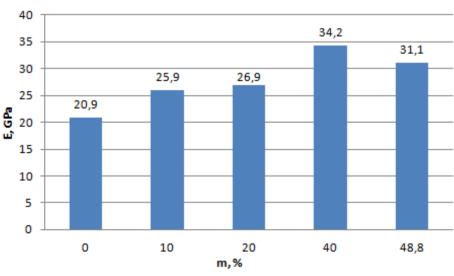


Figure 14. Modulus of elasticity for concrete with various metallic aggregates [8]

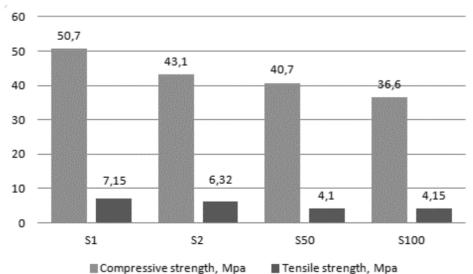
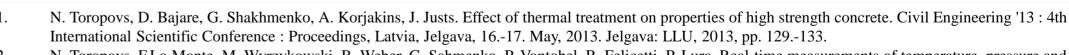


Figure 12. Compressive and tensile strength of the samples [8, 9]

Most significant implemented projects:

•ERAF project Nr. 2010/0286/ 2DP/2.1.1.1.0/10/APIA/VIAA/033 "HIGH EFFICIENCY NANO **CONCRETES**"

•Latvia state research programme project "INNOVATIVE MATERIALS AND SMART TECHNOLOGIES FOR ENVIRONMENTAL SAFETY, IMATEH



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G. Bumanis, G. Shakhmenko, P. Kara, A. Korjakins. Concrete Sawing Waste Recycling as Microfiller in the Concrete Production. Environment. Technology. Resources: Proceedings of the 8th International Scientific and Practical Conference Vol.1, Latvia, Rezekne, June 20-22, 2011. Rezekne, 2011, pp. 346.-352. A. Korjakins, G. Shakhmenko, D. Bajare, G. Bumanis. Application a Dolomite Waste as Filler in Expanded Clay Lightweight Concrete. No: Modern Building Materials, Structures and Techniques: [CD-ROM] Selected Papers of the 10th International Conference, Lietuva, Vilnius, May 19.-21, 2010. Vilnius: Vilnius

Gediminas Technical University, 2010, pp. 156.-161 J. Justs, M. Wyrzykowski, F. Winnefeld, D. Bajare, P. Lura. Influence of Superabsorbent Polymers on Hydration of Cement Pastes with Low Water-to-Binder Ratio. Journal of Thermal Analysis and Calorimetry, 2014, Vol.115, iss.1, 425.-432.lpp. ISSN 1388-6150. e-ISSN 1572-8943.

J. Justs, D. Bajare, G. Shakhmenko, A. Korjakins. Ultra High Performance Concrete Hardening under Pressure. Civil Engineering '11: 3rd International Scientific Conference: Proceedings, Latvija, Jelgava, May 12.-13. 2011. Jelgava: Latvia University of Agriculture, Faculty of Rural Engineering, 2011, pp.

J. Justs, , G. Shakhmenko, D. Bajare. Effect of Different Mix Compositions and Curing Regimes on Ultra High Performance Concrete Compressive Strength. The 10th International Conference Modern Building Materials, Structures and Techniques, Lithuania, Vilnius, May 19.-21, 2010. pp.112.-116.

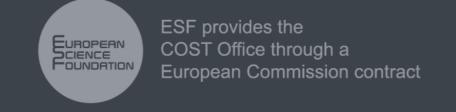
V. Mironovs, J. Bronka, A. Korjakins, J. Kazjonovs. Possibilities of application iron containing waste materials in manufacturing of heavy concrete. Civil Engineering '11: 3rd International Scientific Conference: Proceedings, Latvia, Jelgava, May 12.-13., 2011. Jelgava: Latvia University of Agriculture, 2011, pp. 14.-19

I. Pundiene, V. Mironovs, A. Korjakins, E. Spudulis. Investigation of Hydration Features of the Special Concrete with Aggregates of Various Metal Particles. Key Engineering Materials, 2014, Vol.604, pp. 297.-300.

J. Justs, G. Shakhmenko, D. Bajare, N. Toropovs. Comparison of Pozzolanic Additives for Normal and High Strength Concrete. Environment. Technology. Resources: Proceedings of the 8th International Scientific and Practical Conference, Latvia, Rezekne, June 20.-22., 2011. Rezekne: 2011, pp. 79.-84. D. Bajare, G. Bumanis, G. Shakhmenko, J. Justs. High Performance and Conventional Concrete Propreties Affected by Ashes Obtained from Different Type of Grasses // Tweltfh International Conferencee on Recent Advances in Concrete Technology and Sustainability Issues, Czech republiic, Prague, October 30.-

November 2, 2012. pp. 317.-330. 12. D. Bajare, G. Bumanis, L. Upeniece. Coal Combustion Bottom Ash as Microfiller with Pozzolanic Properties for Traditional Concrete. Procedia Engineering, 2013, Vol.57, pp. 149.-158.











RTU EXPERIENCE IN CONCRETE TEST METHODS CHARACTERISING DURABILITY

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COST action TU 1404

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ABSTRACT. This research focuses on different tests evaluating physical and mechanical properties of the concrete from the point of view of durability. A range of concrete mixes with different additives and aggregates was manufactured and tested.

Frost resistance test, water permeability, water absorption and alkali-silica reactivity test has been performed.

Water absorption is calculated by taking into account mass of water-saturated samples (28 days old) and mass of oven-dried samples. Water absorption is a property, which characterizes an open porosity of the material.

Capillary water absorption of the exposed concrete surface was determined by immersing oven-dry samples in water.

RILEM Test Method 11.4 provides a simple mean for measuring the rate at which water moves through porous materials such as masonry.

RILEM TC 106-2 - Alkali-silica reactivity test is used for detection of potential alkali-reactivity of aggregates.

1. Frost resistance test for ready-mix concrete

The test has been performed in the climatic chamber Sunset 250, using the following regime:

Freezing – in temperature -18 C during 2.5 hours and

Thawing – in temperature +18 C during 2.5 hours.

50 cycles of freezing and thawing test has been performed in fresh water but 8 cycles test - in 5% water solution of NaCl. (ΓΟCT 10060.1-95).

Frost resistance tests of trasport concrete

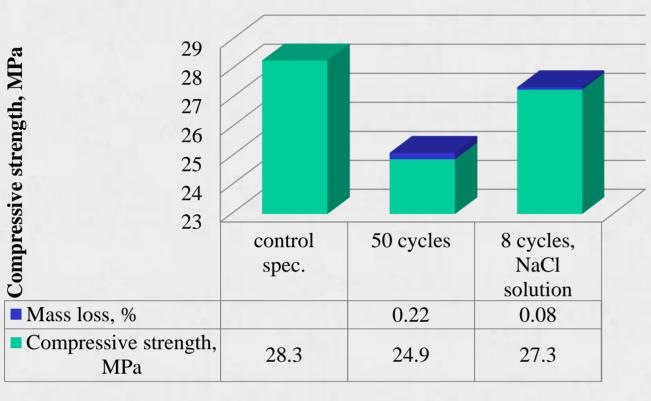


Fig 1. Results of the freezeing-thawing cycle test. Amount of specimens - 6 pieces for each test

3. Capillary water absorption test

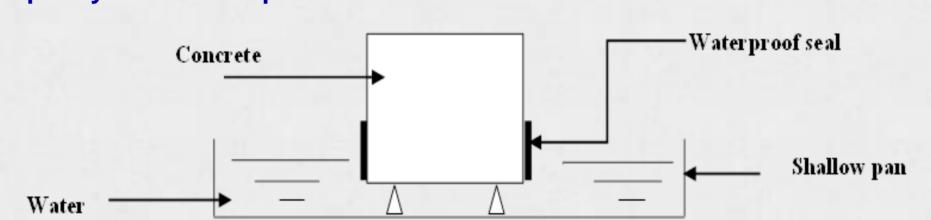


Fig 5. Sample preparation for the capillary water absorption test, the sides of the cubes were sealed with resin

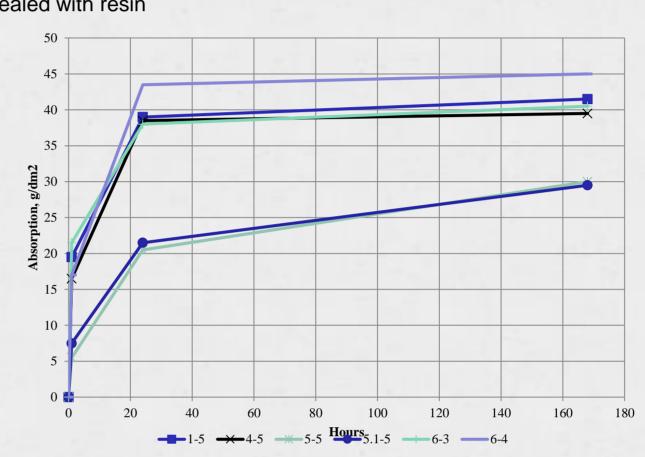


Fig 6. Results of the capillary water absorption test

2. Frost resistance test of paving bricks

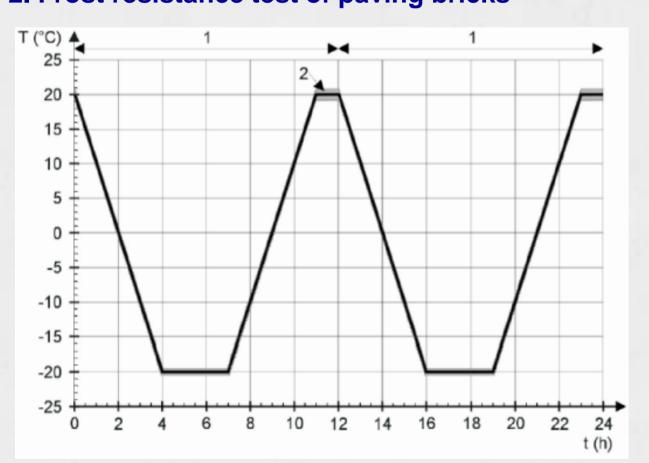


Fig 2. Freezing – thawing cycle of paving stone by LVS

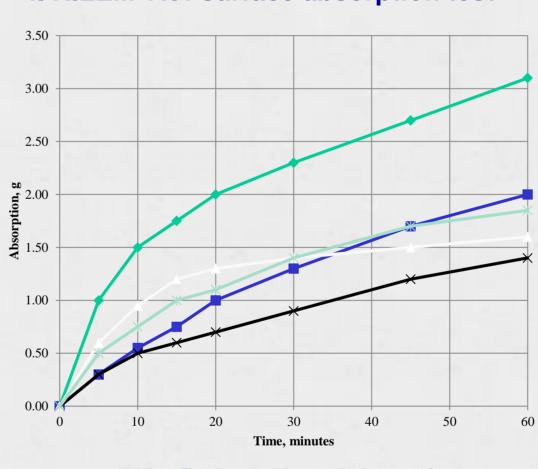
CEN/TS 12390-9 standard

The test has been performed in the following order:

Freezing – within 4 hours temperature is gradually reduced to -20 C and kept in this temperature for 3 hours.

Thawing – within 4 hours temperature is gradually rised to +20 C and kept in this temperature for 1 hour.

4. RILEM 11.4 surface absorption test



This test method 11.4 is a simple mean for measuring the rate at which water moves through porous materials (such as masonry). The test can be performed at the site or in the laboratory and can be used to measure vertical or horizontal water transport. Water permeability measurements obtained in the laboratory can be used to characterize unweathered. untreated masonry. Measurements made at the site (or on samples removed for laboratory testing) can be used to assess the degree of weathering that the material has undergone. Test Method 11.4 can also be used to determine the degree of protection afforded by a water repellent treatment.

Fig 7. Results of the RILEM 11.4 surface absorption test

SUNSE

Fig 3. Climatic chamber





Fig 4. Surface of 2 paving stones after 28 cycles of freezing-thawing

5. ASR reaction test for determining the reaction between expanded glass granules and binder inside the structure of lightweight aggregate concrete

Alkali-Silica reactivity (ASR) test was performed for lightweight concrete specimens with 8 different types of cement. ASR was tested according to RILEM TC 106-2 - Detection of potential alkali-reactivity of aggregates -The ultra-accelerated mortar bar test. 40x40x160mm prismatic samples were molded, then after 24+2 hours of hardening, samples were demolded and stainless steel pins were attached. During the next 24 hours samples were hardened in water at 80°C and right after that zero reading for samples were measured. Samples were kept in 1M NaOH solution at 80°C and ASR expansions were measured for 14 days.

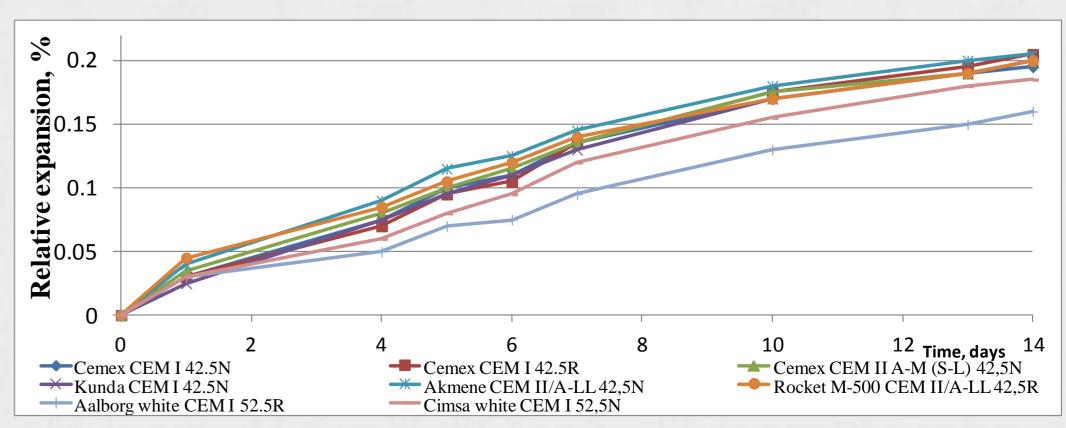


Fig 8. ASR according to RILEM TC 106-2-14days in 1M NaOH solution at 80C for different types of cement











Research in Cement Bound Materials & Concrete Structures

Materials Engineering & Sustainable Construction, Faculty for the Built Environment, University of Malta.

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Faculty for the Built Environment, Research in CBM & Concrete

- The University of Malta is the highest teaching institution in Malta. There are some 11,500 students including over 750 international students from 82 different countries. The Faculty for the Built Environment at the University of Malta embraces a wide range of areas including also Structural and Civil Engineering, Reinforced and Prestressed Concrete Structures, Engineering Materials, Concrete Technology and Sustainable Construction.
- Research in Cement and Concrete focuses on the utilisation of waste materials and byproducts in concrete and cement replacement materials. high performance concrete, high strength, fibre reinforced concrete, aerated concrete and self consolidating concrete.
- The facilities include laboratories for materials characterisation, CBM Microstructure analysis, chemical analysis, shrinkage behaviour and cracking, rheology and thixotropy of concrete, mechanical properties, transport processes, concrete durability and degradation mechanisms including chloride penetration, corrosion, sulphate attack in concrete.

Waste Materials Recycling, by-products and cement replacement.

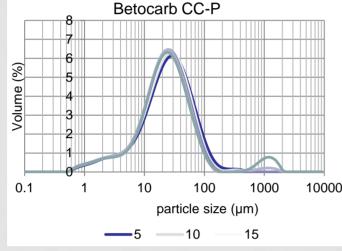
- Research focuses on the use of a variety of waste products in concrete including aggregate and cement replacement materials. The use of by-products and cement replacement materials refers in particular to; waste Limestone Filler, PFA (Pulverised Fuel Ash), Silica fume and Metakaolin.
- Other waste products assessed include; Recycled Concrete Aggregate, waste tyre rubber and waste tyre fibres, PET, Glass. The experimental materials research aims at the development of low impact materials and is supported by characterisation and classification of materials, Radio-Nuclide Analysis and Life Cycle Assessment.

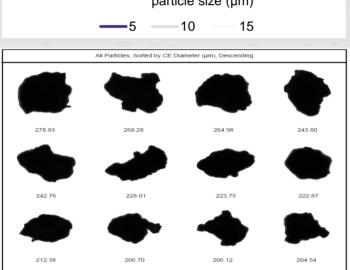


Materials Characterisation, Microstructure Analysis

- Characterisation of materials is carried out using specific advanced tests, for different materials.
- Microstructural analysis of CBM







Physical Analysis

- Relative Density
- True Density (Helium Pycnometer)
- Moisture Content, Water Absorption
- Particle Size Distribution
- Laser Diffraction Analysis
- Morphologi G3
- BET Specific Surface Area
- Blaine Specific Surface, Fineness

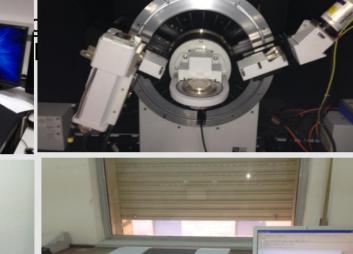
Chemical Analysis

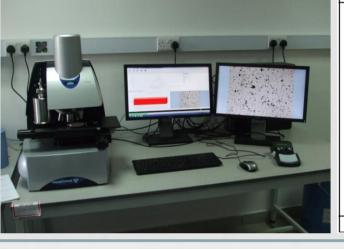
- SEM EDS Analysis
- XRF, XRD Analysis
- FTIR Analysis
- LOI, Insoluble Residue
- Limestone content
- Pozzolanicity

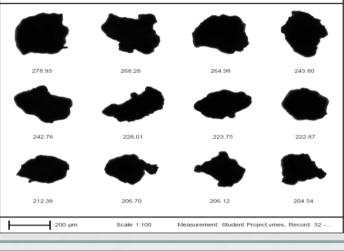
Paste Analysis

- Mercury Intrusion Porosimetry (MIP) Consistence & Setting time
 - pH water leaching solution















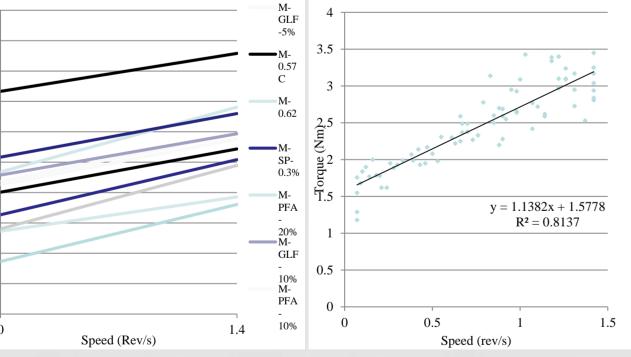




Rheology and Thixotropy of CBM, Self Compacting Concrete





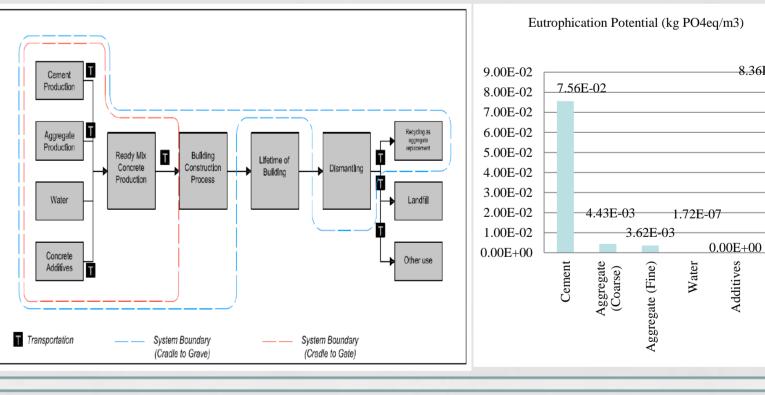


- Rheology of concrete is assessed using single point tests and also the two point test using the New Concrete Rheometer, designed and constructed specifically to assess the characteristics of a wide range of fresh concrete mixes inc. self-compacting concrete.
- The Rheometer is based on a rotating impeller and the torque, power and speed data is logged and allows for the determination of the rheology characteristics and the Thixotropy of concrete.
- A shear-vane experimental setup was also developed for the assessment of Thixotropy of concrete.

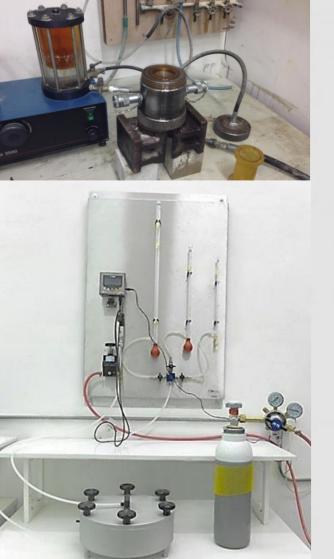


Environmental Profile & Life Cycle Analysis

- A software tool for the determination of the environmental profile for aggregate and concrete was developed. The software tool allows the life cycle assessment of concrete with respect to different boundary conditions set.
- The Assessment is carried out with respect to Impact Categories; Embodied energy and Embodied Carbon, Global Warming, Acidification, Eutrophication and POCP Potential.



Transport Properties & Degradation of CBM





- Porosity Vacuum Saturation
- Water permeability EN 12390-8-2009
- Water Permeability Steady State
- Oxygen Permeability UNI 11164:2005
- Air Permeability & Water Absorption (Figg Test)
- Rapid Chloride Permeability Test (RCPT) ASTM C1202
- Rapid Chloride Migration Test (RMT) NT Build 492
- Chloride Penetration Test (CPT) NT Build 443
- Chloride Migration Diffusion Coeff. (CMD) NT Build 355
- New Accelerated Carbonation Chamber (T, RH, CO₂).



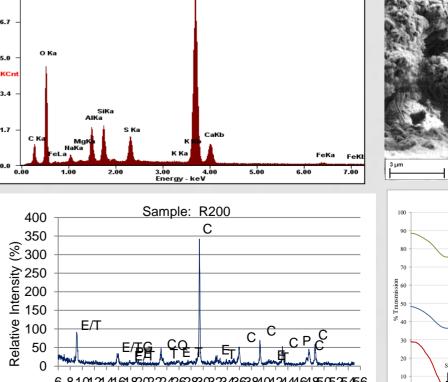


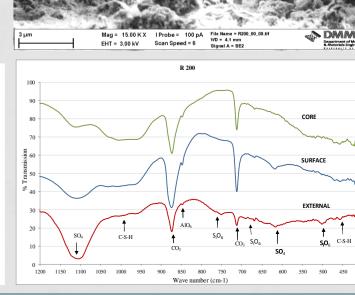
Sulphate Attack in Concrete.

Sample Conditioning Chambers.

c:\edax32\genesis\genspc.spc 12-Nov-2013 12:35:27 Chlorite (Nrm.%= 38.86, 20.96, 34.83, 1.14, 3.84, 0.28)

- Detailed analysis of degradation is carried out using advanced techniques namely XRD, FTIR, SEM and EDS.
- Microstructure assessment HP and MIP.







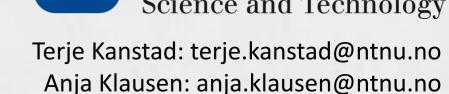


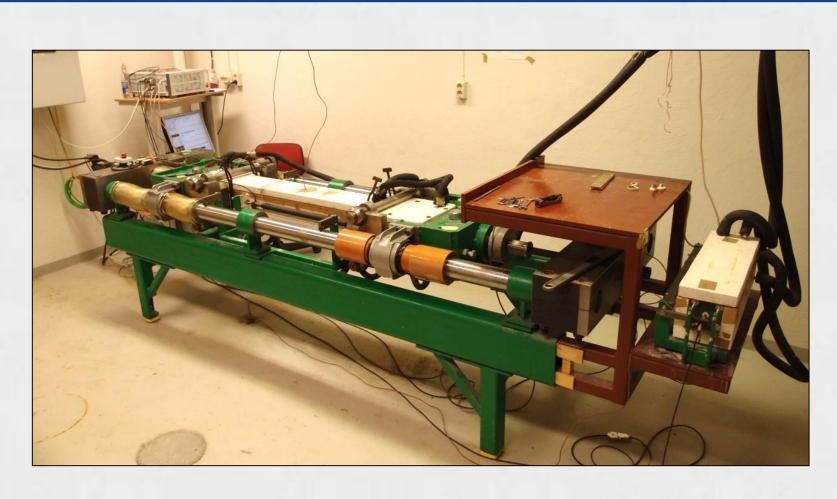




The Temperature-Stress Testing Machine (TSTM) System







Available Measurements:

- Free deformation: thermal dilation and autogenous deformation
- Restrained stress development
- E-modulus development
- Creep/Relaxation in tension and compression
- Coefficient of Thermal Expansion (CTE)

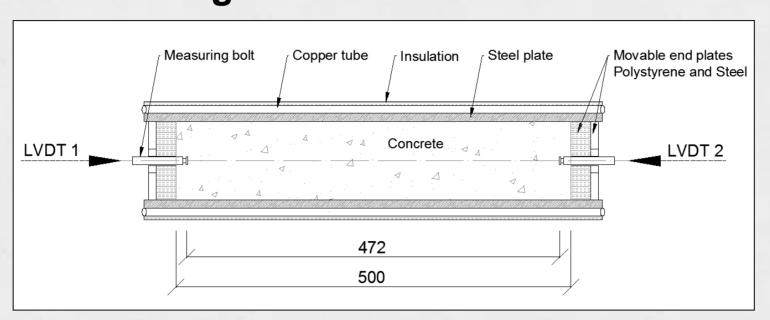
Temperature controlled:

Isothermal or realistic temperature histories during testing

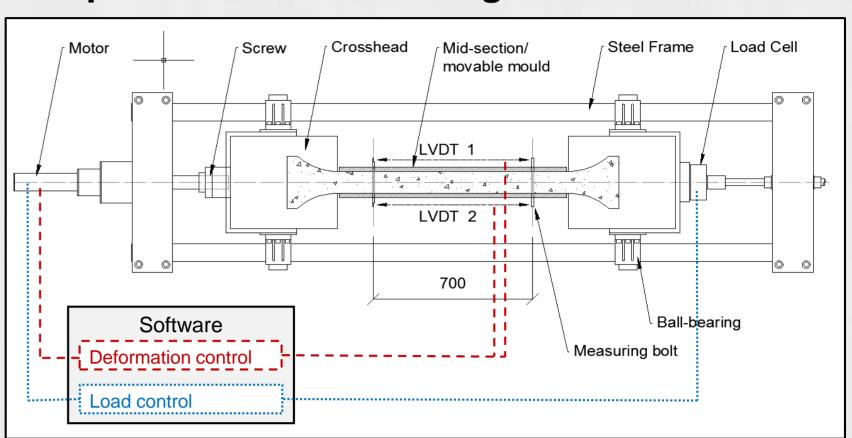
Components:

- The Dilation Rig free deformation in the hardening phase
- The Temperature-Stress
 Testing Machine
 stress development in the
 hardening phase at a chosen
 degree of restraint.

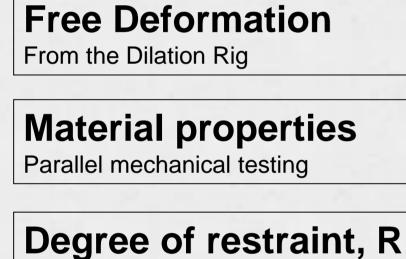
Dilation Rig



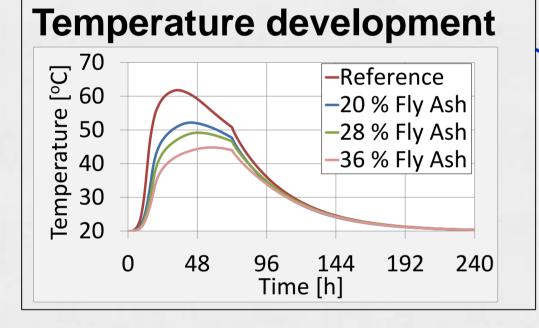
Temperature-Stress Testing Machine

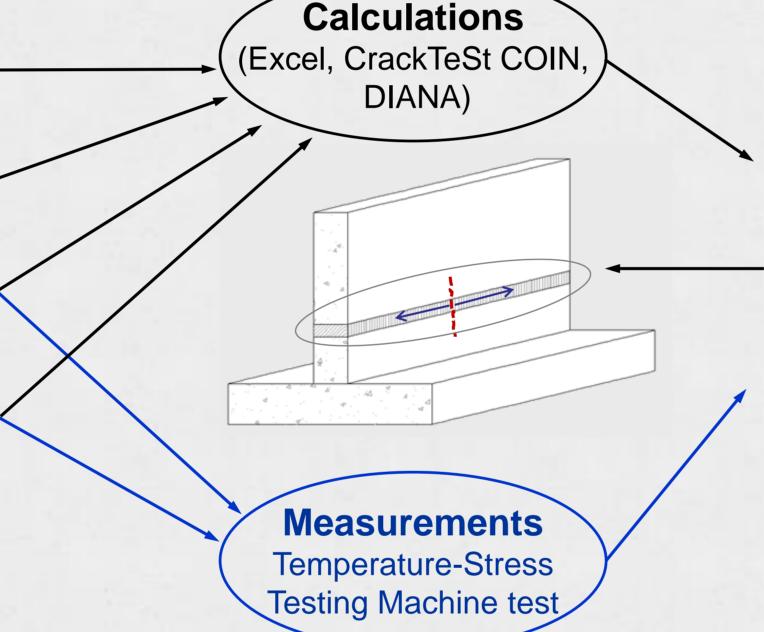


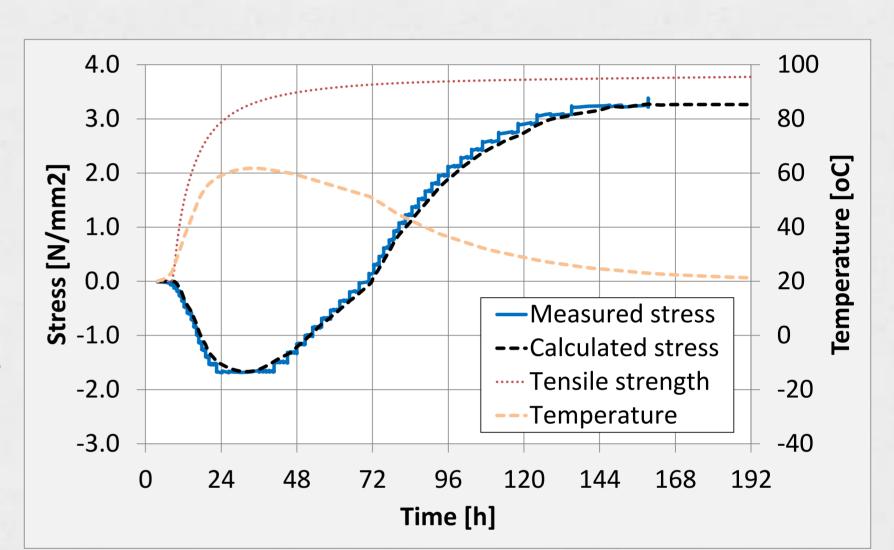
Test Results and Calculation Approaches:



The concrete's ability to move





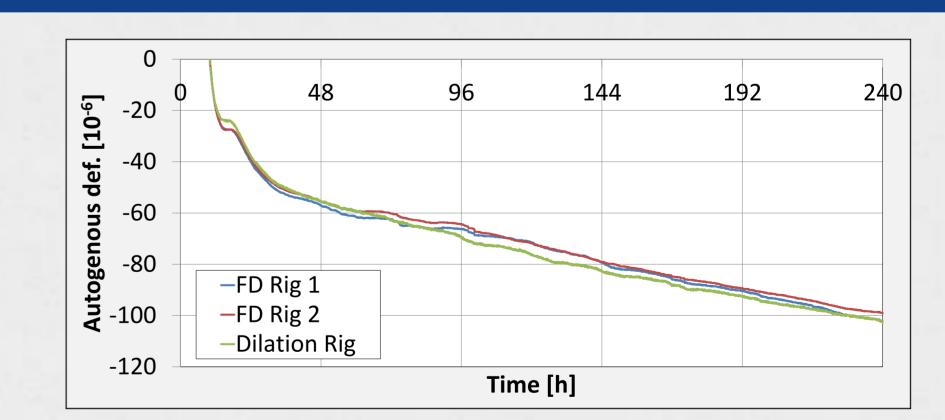


The Temperature-Stress Testing Machine is able to directly simulate the strain- and stress development during the hardening phase in a selected section of a concrete structure

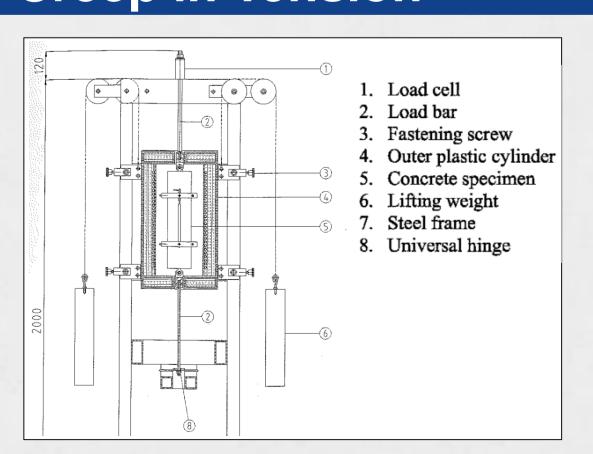
The Free Deformation (FD) System



- Free deformation:
 thermal dilation and autogenous deformation
- 7 Rigs
- Temperature controlled: Isothermal or realistic temperature histories



Creep in Tension



- 1 Rig
- Temperature controlled: Isothermal or realistic temperature histories

Creep in Compression



- 7 Rigs
- Isothermal conditions

1st Workshop TU14040 Ljubljana, April 16th – 17th, 2015









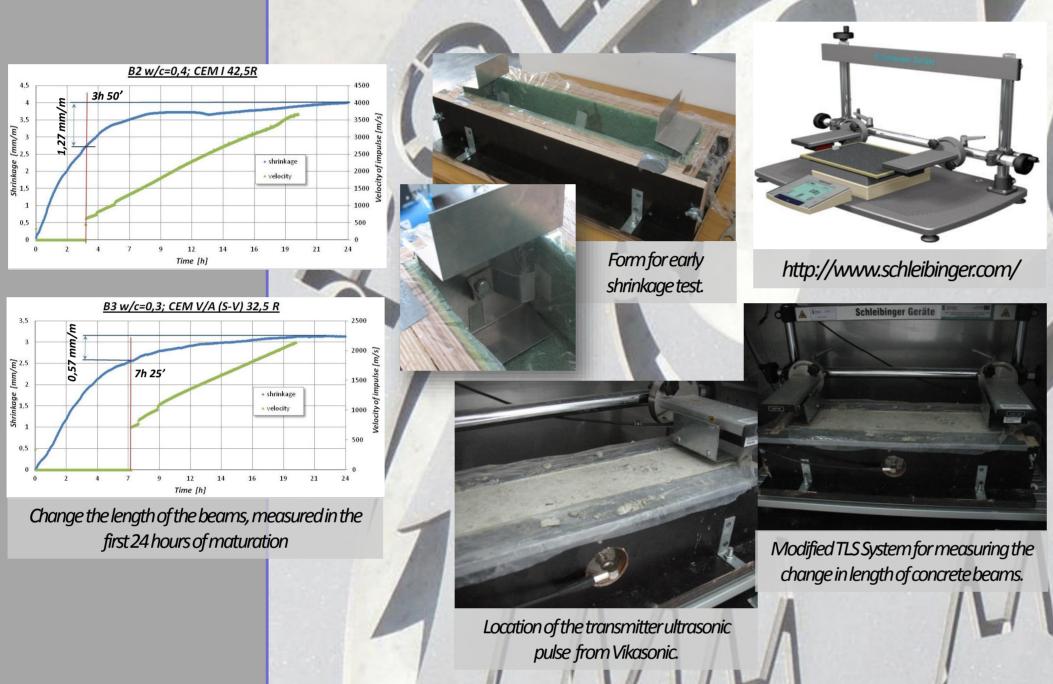


SILESIAN UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering Department of Building Materials and Processes Engineering Akademicka 5 Str., 44-100 Gliwice, Poland

Our laboratory has equipped to realize a wide range of researches in the field GP1.a. Apart from standardized tests fresh and hardened concrete (according to european standards) we specialize in the study of the rheological properties of fresh concretes, mortars and cement pastes. In research we use the rheometers XL, NT, PC and BT2.





We have laser systems for testing shrinkage or expansion of mortars - Shrinkage cone and Thin Layer Shrinkage System. TLS system is a device originally designed for testing early shrinkage or expansion of thin mortars, like self-leveling flooring compounds. In our laboratory, TLS system was modified. As a result, it is possible to measure the shrinkage of concrete beams 10x10x50cm. An additional advantage is the use of Vikasonic system that allows to determine the setting time.

Pressure-Measuring System (produced by SPAIS according our specification).

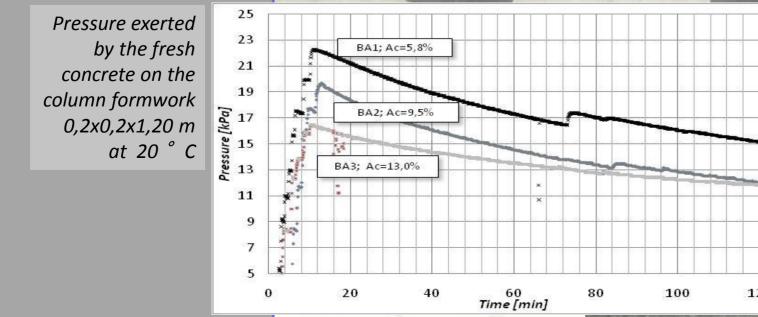
A system for determining formwork pressure of concrete, suitable both for vibrated and self-compacting concrete. Records changes in J the value of pressure with time. Adequate sensitivity can measure changes in the pressure caused by thixotropic effects.

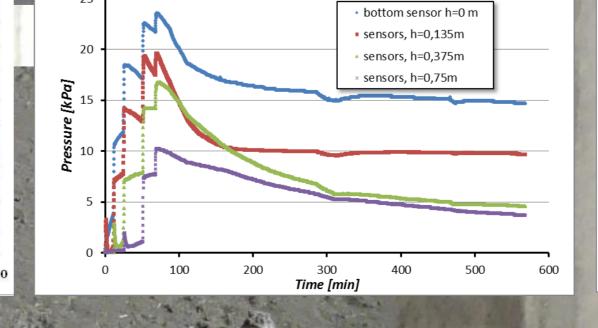
The system includes:

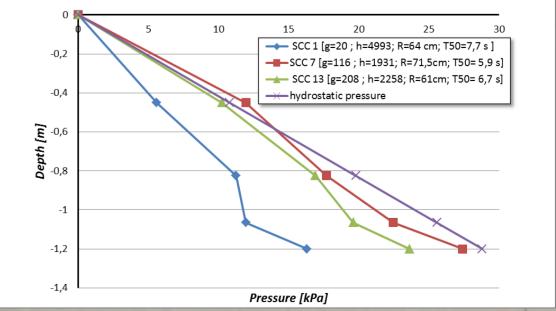
- •8 strain gauge pressure transducers
- Analog Digital Converter
- Computer recording measurements

System was widely used in the project "The influence of time and technological factors on rheological properties of self-compacting concrete in terms of the pressure on the formwork" financed from the National Science Centre in Cracow No. 0842/B/T02/2011/40 (2011-2014)













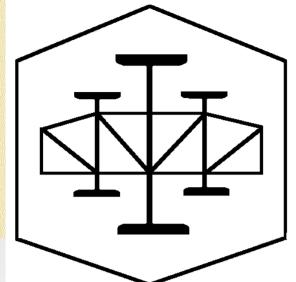




Wrocław University of Technology

Faculty of Civil Engineering

Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, POLAND



REASERCH POSTER

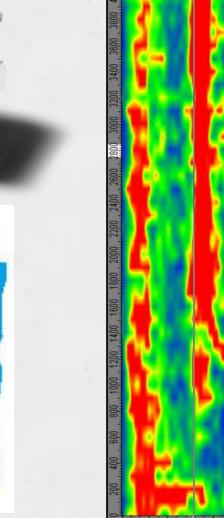
Krzysztof SCHABOWICZ

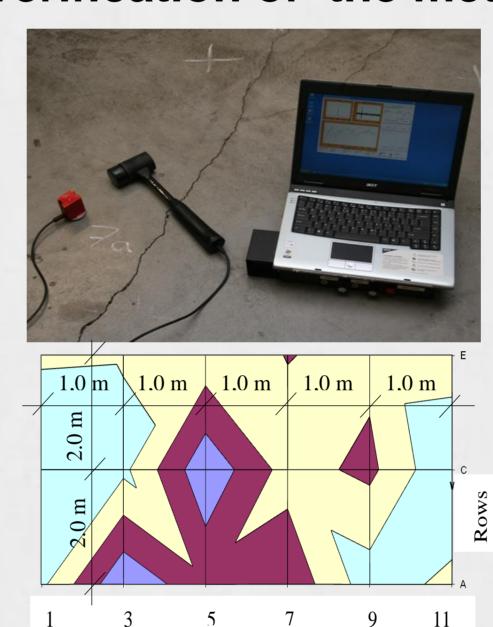
My most important scientific and research achievements are:

- 1. The development of the original methodologies for the non-destructive determination of
 - a) incorrect thickness
 - b) delaminations
 - c) identification and location of zones of concrete macroheterogeneities
 - d) location of large air voids
 - e) the depth of cracks

in unilaterally accessible concrete structures by means of the ultrasonic tomography method, impulse response, impact-echo as well as the combined use of these methods, and the on-site verification of the methodologies.

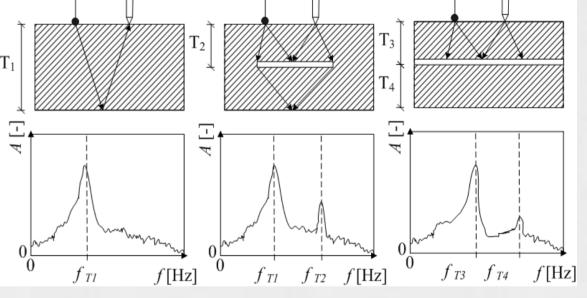






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- 2. The creation of the knowledge base based on laboratory tests, the analysis of the test results and the verification and fine-tuning of the original methodologies for the non-destructive determination of selected geometric and material imperfections in unilaterally accessible concrete structures by means of the state-of-the-art acoustic methods.
- 3. The assignment of the non-destructive acoustic methods to the testing of the selected imperfections in unilaterally accessible concrete structures and the proposal of terms describing the imperfections.
- 4. I was one of the first persons in Poland to apply the ultrasonic tomography method to the testing of the selected geometric and material imperfections in unilaterally accessible concrete structures.

A list of most important scientific/research papers related to the COST Action TU1404:

https://www.scopus.com/authid/detail.url?authorld=55897182700 http://www.researcherid.com/rid/B-6040-2015

http://orcid.org/0000-0001-6320-9539







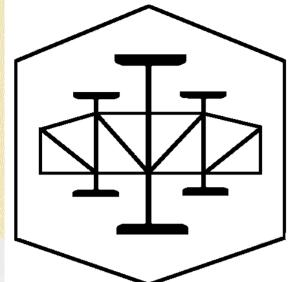




Wrocław University of Technology

Faculty of Civil Engineering

Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, POLAND

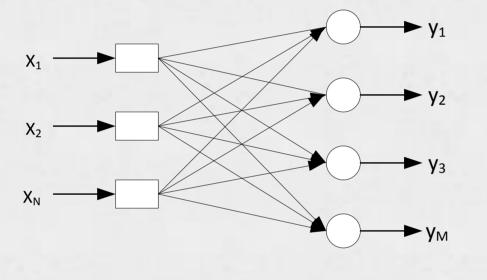


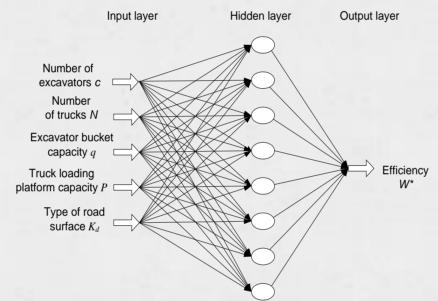
REASERCH POSTER

Krzysztof SCHABOWICZ

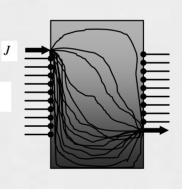
Another research work relating to:

- 1. the extension of the tests and the knowledge base to cover self-compacting concretes and concretes with a fly ash addition for the purposes of identifying the compressive strength of concrete by means of artificial neural networks on the basis of parameters evaluated by non-destructive methods;
- 2. the use of artificial neural networks in solving problems relating to the productivity of systems of earth-moving machines, consisting of excavators and hauling equipment;
- 3. the co-development of a non-destructive impedance tomography method for identifying the moisture content in brickwork;
- 4. the co-development of a production and testing technology for fibre cement boards.



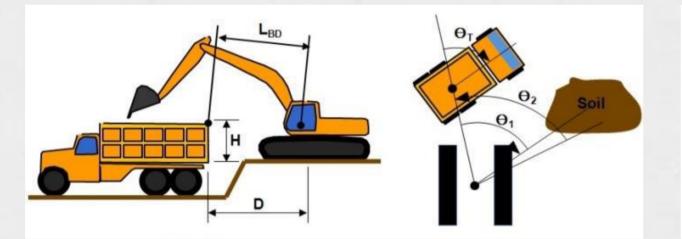


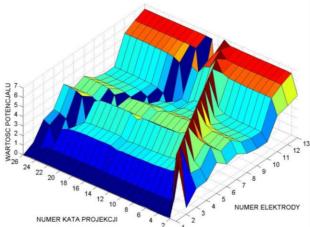












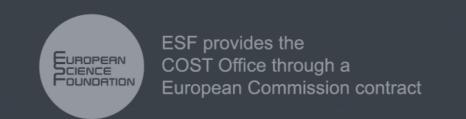




Management of international and national research projects and participation in such projects

- 1. Ministry of National Education research project no. 4 TO7E 045 entitled: "New tomographic method of assessing the degree of moisture accumulation in brick walls in building structures" contractor.
- 2. Innovative Economy project contractor: innovative measures and effective methods of improving the safety and durability of building structures and transport infrastructure in the sustainable development strategy, co-funded from the European Regional Development Fund under the Innovative Economy Operational Programme 2007-2013, No. POIG.01.01.02-10-106/09-00, Measure 1.1, Sub-measure 1.1.2, order No. 251040/I-14, research topic 6.2, 2007 2013.
- 3. Innovative Economy project contractor: Innovative Economy: UDA-POIG.04.04.00-02-019/08, "Starting the innovative production of eco-friendly cellulose fibre-cement boards", co-funded under Measure 4.4 New Investments of High Innovation Potential, Innovative Economy Operational Programme 2007 2013.











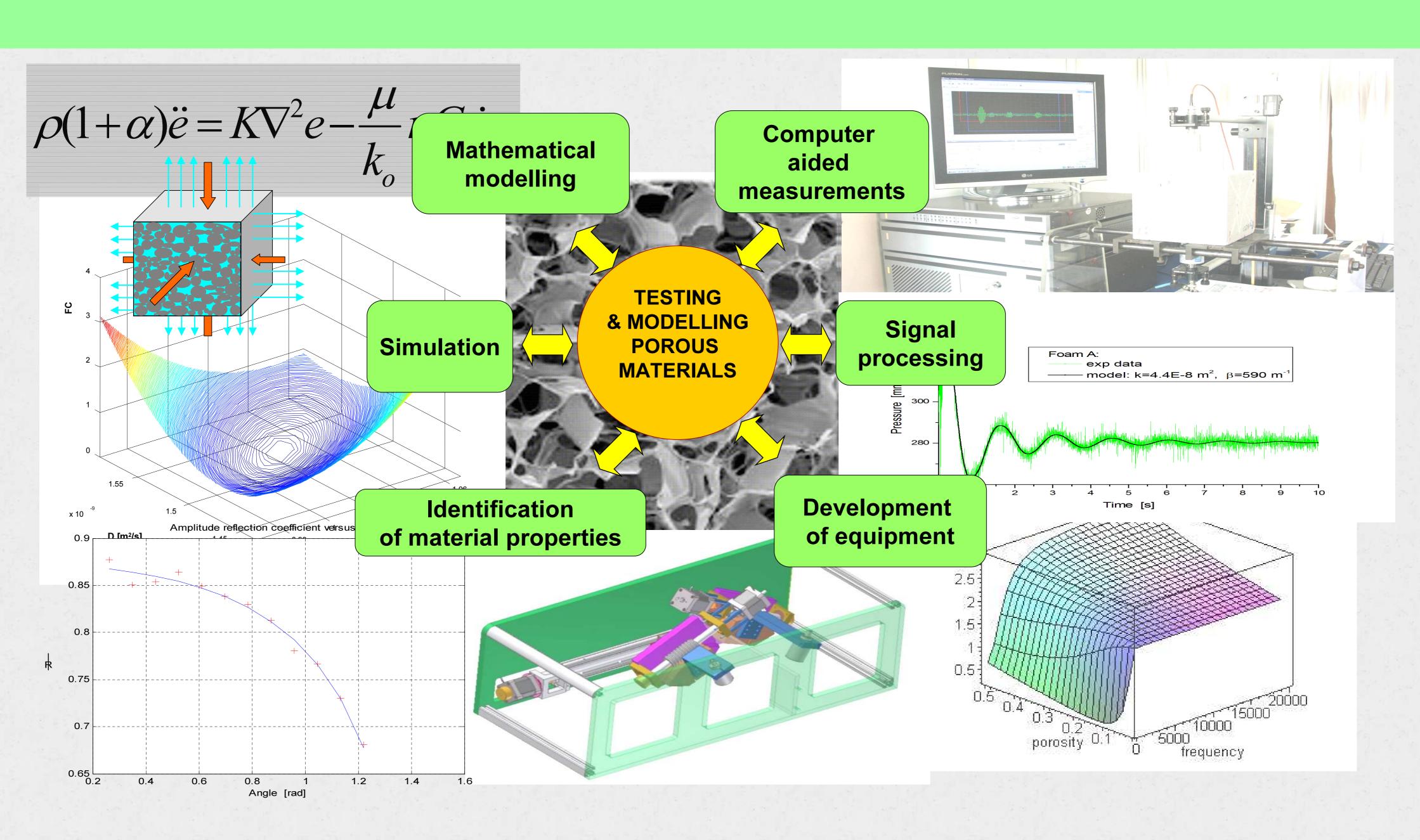
Kazimierz Wielki University





Institute of Mechanics and Applied Computer Science (IMACS)

imis@ukw.edu.pl



MAIN ACTIVITIES:

- ☐ Modelling and simulation of coupled processes of deformation, flow and transport,
- ☐ Modelling internal structure, constitutive description, micro macro upscaling,
- ☐ Development of methods of identification of material properties, model based approach,
- ☐ Application of optimization techniques for model calibration,
- ☐ Development of image processing techniques,
- □ Experimental investigations of porous and inhomogeneous media using US non-contact techniques,
- ☐ Porosimetry, studies of permeability, tortuosity, mass diffusion and sorption,
- ☐ Studies of evolution of wave properties due to maturing and aging.

SELF DEVELOPED TECHNIQUES FOR STUDIES OF CBM:

- ☐ Ultrasonic non-contact (air coupled) methods with different modalities:
 - echo,
 - transmission,
 - surface wave,
 - plate wave and,
 - reflectometry;
- ☐ Air and water permeability testing:
 - stationary and
 - non-stationary methods.

IMACS in numbers:

Research staff	Technical staff	PhD students	TOTAL
27	10	14	51 (F 12)

Contact: prof. Mariusz Kaczmarek

Institute of Mechanics and Applied Computer Science

Kopernika 1, 85-074 Bydgoszcz, Poland

tel: +48 52 3257613/650

e-mail: mkk@ukw.edu.pl or imis@ukw.edu.pl

























José Granja¹
Miguel Azenha¹
Cyrille Dunant²

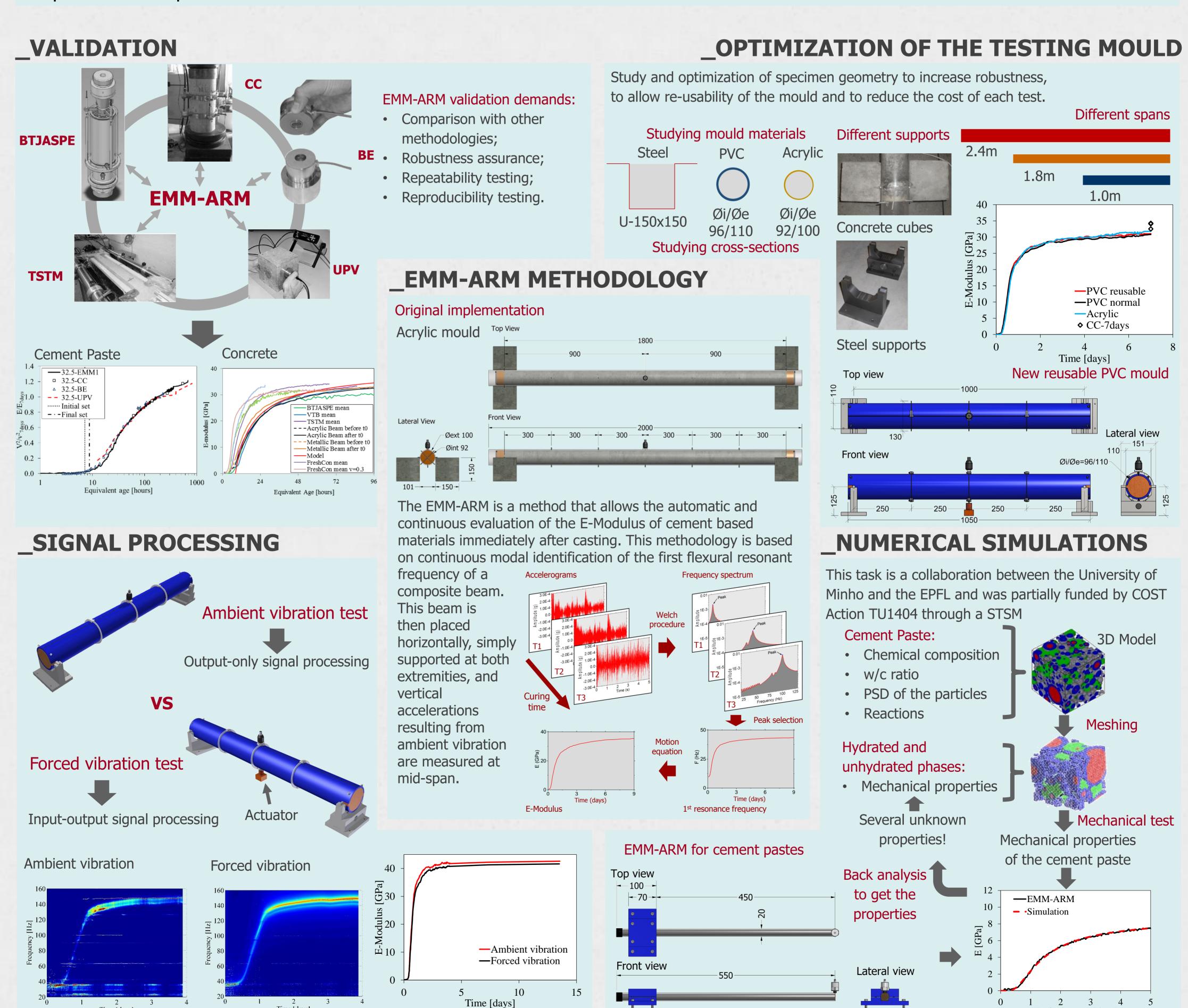
¹University of Minho, Portugal ²EPFL, Switzerland



Continuous characterization of stiffness of cement-based materials: experimental analysis and micro-mechanics simulation

_SCOPE OF THE WORK

- Comprehensive validation of the methodology termed "Elasticity Modulus Monitoring through Ambient Response Method" (acronym: EMM-ARM) that allows continuous monitoring of the E-modulus of cement-based materials since casting.
- Introduce improvements to the EMM-ARM for overcoming its current limitations for systematic application (lab and in-situ).
- Optimization of EMM-ARM for continuous monitoring of the modulus of elasticity of cementitious materials.
- Perform microstructural modeling of the stiffness evolution of cementitious materials by taking advantage of unprecedented quantitative experimental data obtained with EMM-ARM.





Time [days]

Time [days]







Equivalent age [days]













Luís Leitão
Supervisors: Rui Faria (FEUP)
Miguel Azenha (UMinho)

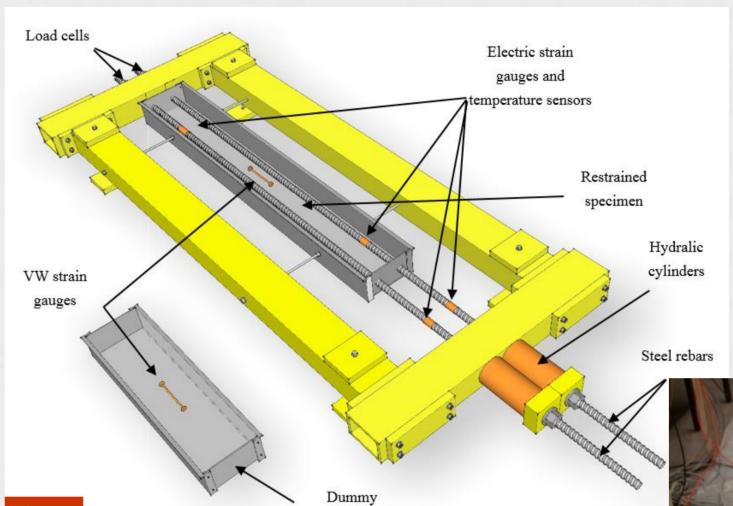
THERMO-HYGRAL-MECHANICAL APPROACH TO SELF-INDUCED STRESSES IN CONCRETE STRUCTURES

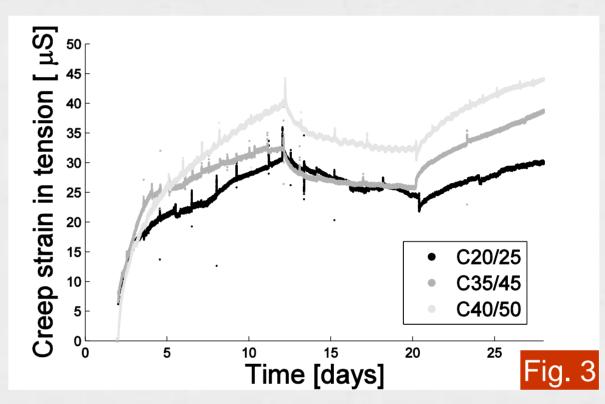
☐ SCOPE

- The aim of the present PhD is to develop a Thermo-Hygro-Mechanical (THM) numerical model to predict the concrete stresses and cracking since casting and throughout service life.
- This numerical framework is supported on advanced experimental methods for material characterization, namely the assessment of creep in tension and the relative humidity (RH) in concrete.



- Fig. 1 and Fig. 2 present an innovative Variable Restraining Frame (VRF), developed to characterize the viscoelastic behavior of concrete in tension, when subjected to tensile stresses induced by restraints to shrinkage deformations.
- In Fig. 3 is possible to observe the creep strain in tension associated to 3 different experimental tests.



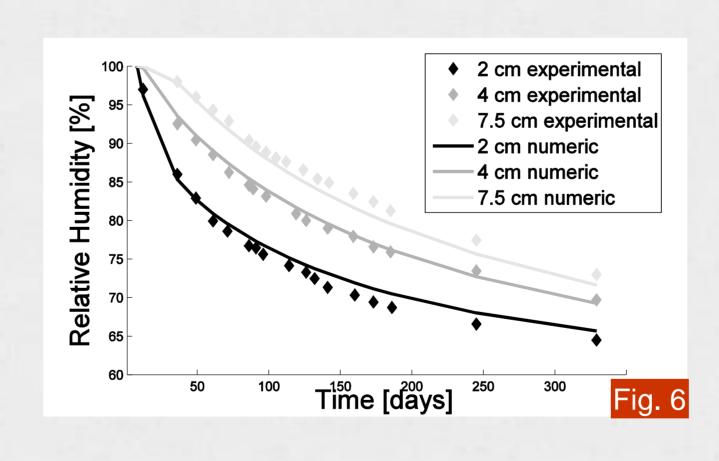


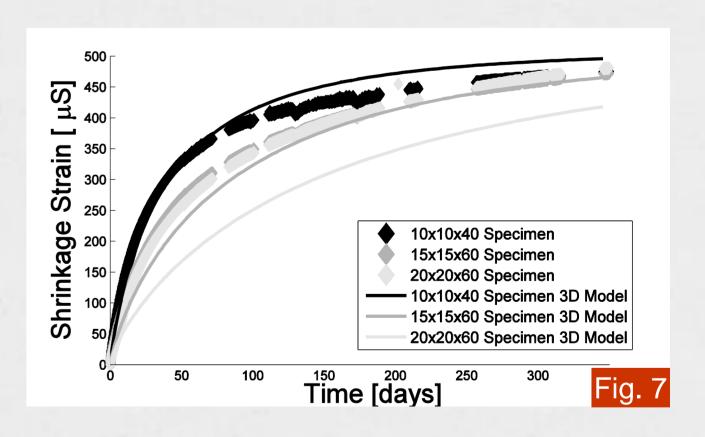


☐ RH AND SHRINKAGE: EXPERIMENTAL WORK AND NUMERICAL MODELLING

Validation and calibration of the THM model is achieved by experimental measurements of the RH in concrete specimens at different depths (Fig. 4), with recourse to Vaisala hygrometer (Fig. 5). In Fig. 6 and Fig. 7 is possible to observe the comparison between experimental and numerical results of the RH and shrinkage strains.

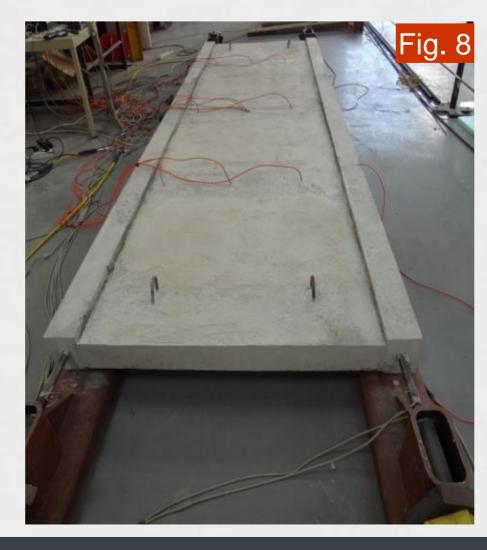






☐ THM MODELLING OF REINFORCED CONCRETE STRUCTURES

- Development of a real-size experimental RC concrete structure in laboratory conditions (Fig. 8). Hydraulic cylinders are used to control a variable restriction. Parameters associated to the THM model well characterized (VRF test, mechanic characterization and humidity measurements).
- Fig. 9 represents the associated 3D THM model and Fig. 10 is a schematic of the numeric crack pattern.



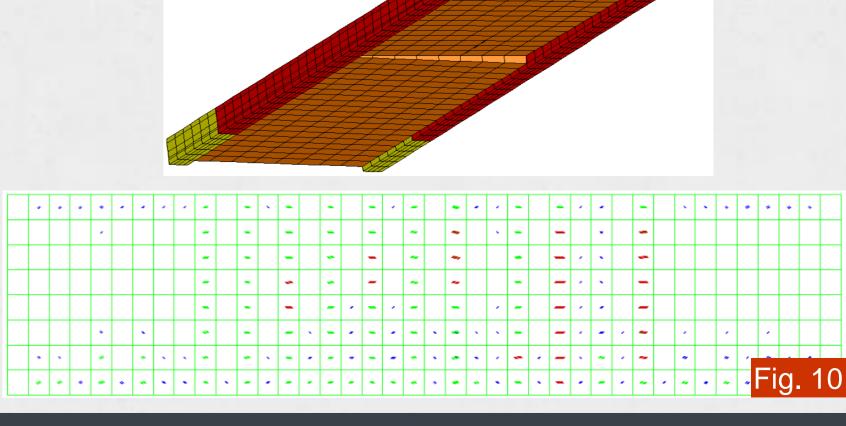






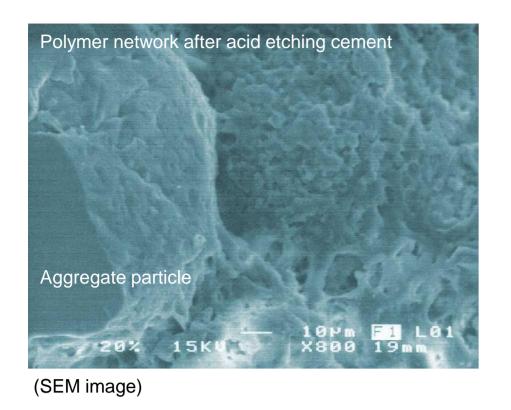


Fig. 9



Polymer-modified cement mortars for concrete repair

RESEARCH MOTIVATION



The improvements achieved with polymer-modification of cement-based materials result from the polymer – cement co-matrix, which starts to form at a 10% polymer to cement mass ratio and has a distinct pore structure.

ULTIMATE GOAL

Concerning the efficiency of polymer addition in tensile strength of cement materials, attempts have been made to develop different test methods to evaluate tensile strength as an essential feature to individually explain each possible mechanism involved.

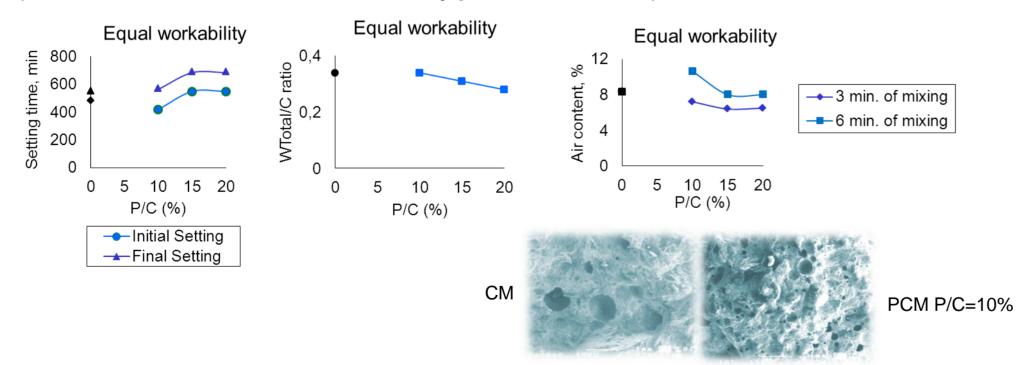
MORTAR FORMULATION

Natural siliceous sand and cement CEM I 42,5 R were used. The polymer modifier added consisted of styrene-butadiene dispersions (SB).

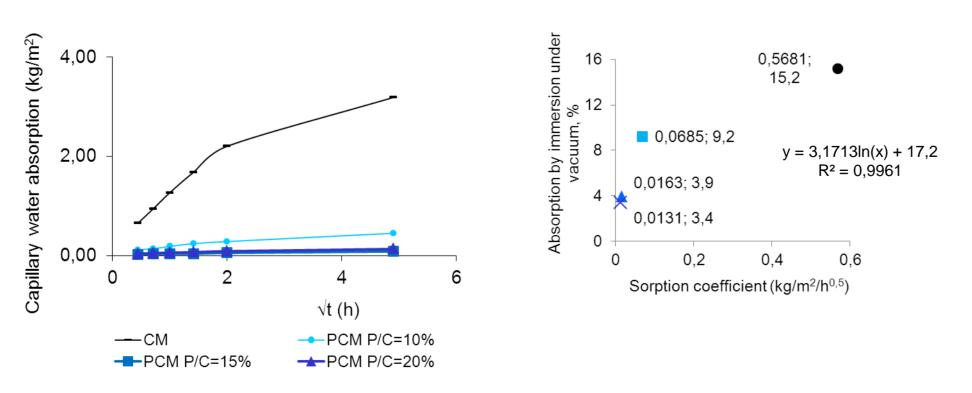
A mass cement:sand ratio of 1:3 was adopted for the mortar composition, with sufficient consistency for common use (flow consistency of 110 %, ASTM C 1437). Properties of polymer-modified cement mortars (PCMs) were compared to those of a non-modified cement mortar (CM), with similar flow.

W/C RATIO, SETTINGS AND AIR CONTENT

Polymers have air entraining and plasticizing effects, hence reducing the required W/C ratio of mortar for a given flow, and retarding the hydration of cement particles (EN196-3, ASTM C 231- type B meter).



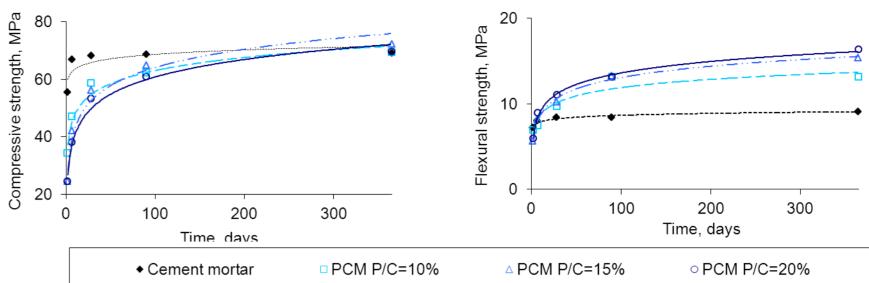
CAPILLARY WATER ABSORPTION

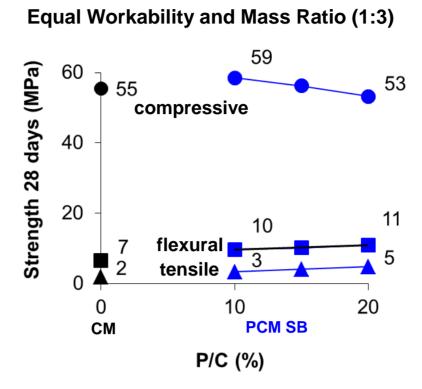


PCMs exhibited much less capillary water absorption (EN 13057) than CM and a good correlation was found between sorption coefficient and absorption of water by immersion under vacuum of mortar specimens.

COMPRESSIVE AND TENSILE STRENGTHS

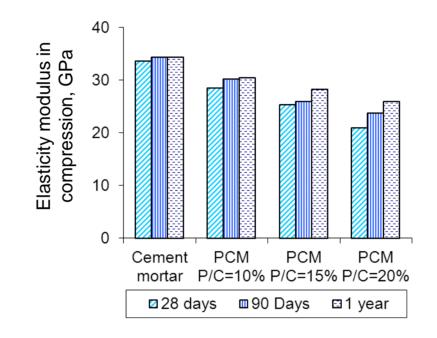






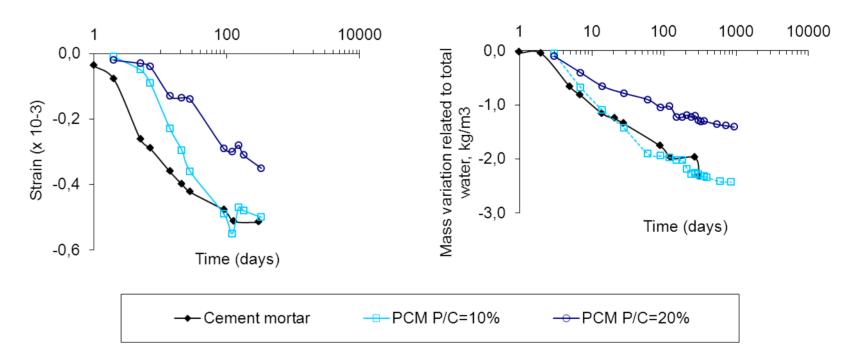
Tests performed on PCM confirmed the beneficial action of polymers on tensile strength and, in particular, on flexural strength of cement mortars, whereas in compressive strength, a reduction, at earlier ages, was observed (EN 12190).

STIFFNESS AND UNRESTRAINED STRAIN IN AIR

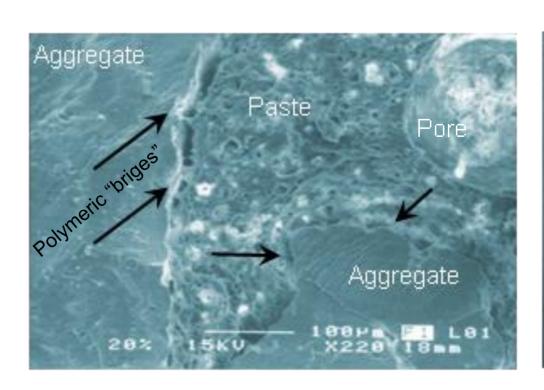


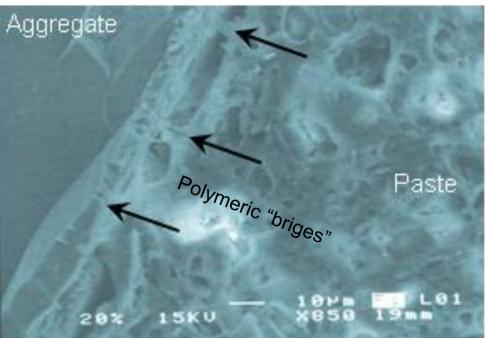
The crystalline atrophy of the hydrated $Ca(OH)_2$ and the hindrance of the hydrated calcium silicate gel, due to polymer presence reduces the stiffness of the mortar (EN13412).

The barrier to the exit of the free internal water created by the polymer film, which increases the capacity of water retention inside the paste, provides the PCM with an internal cure that reduces the shrinkage (EN 12617-4) and, consequently, the microcraks.



MICROSTRUTURE BUILDING IN PCM





SEM images revealed the present of polymeric "bridges" at the transition zone between the aggregate and the polymer cement binder of PCM.



Maria Sofia Sousa Ribeiro Research Officer sribeiro@Inec.pt www.Inec.pt



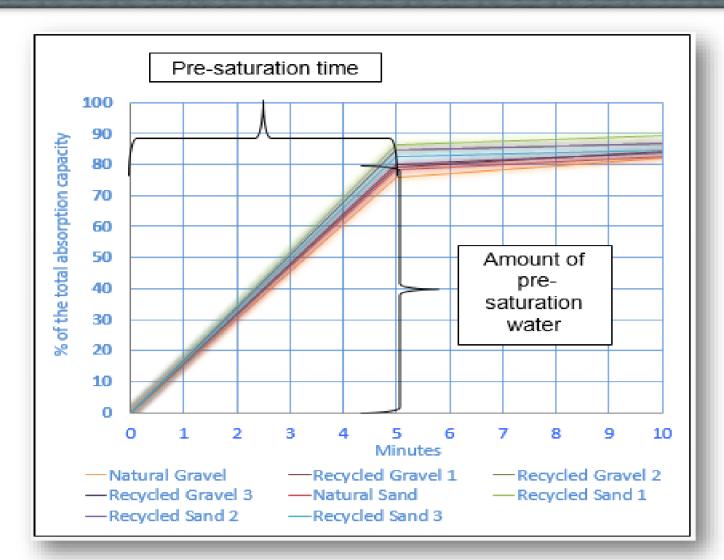






FORFUGAL

Mitigation of the Negative Effects of Recycled Aggregate Water Absorption in Concrete Technology



The main problem of recycled aggregate is its high water absorption capacity. This property has negative effects on cement based materials in their fresh and hardened state. To overcome this problem it was developed methods to optimize a staged mixing approach.



No water exchange No water exchange No water exchange No water exchange Recycled Aggregate 1 Concrete Recycled Aggregate 2 Concrete Recycled Aggregate 3 Concrete

Disadvantages

Negative effects on natural aggregate cement based materials;

Need to know the water absorption capacity of the aggregates

Longer mixing time

Advantages

Reduces workability decrease

Reduces effective W/C ratio

Develops stronger aggregate-cement paste bond strength

Increases strength

Reduces shrinkage

Reduces plastic shrinkage cracking

Recent Research Projects:



• Self- compacting concrete with controlled shrinkage, PHD Thesis, University of Coimbra-Portugal, Miguel Oliveira



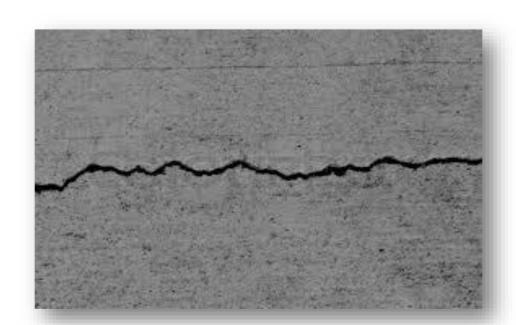
- Evaluation of the influence of early age shrinkage on the control of concrete cracking; Master Thesis, University of Évora Portugal, Matthias Eckert
- Combined effect of expansive and shrinkage reducing admixtures to control autogenous shrinkage in self-compacting concrete, Construction and Building Materials 52 (2014) 267–275, José Oliveira, M.; Ribeiro, A.B.; Branco, F.G



- Curing effect in the shrinkage of a lower strength self-compacting concrete, Construction & Building Materials, José Oliveira, M.; Ribeiro, A.B.; Branco, F.G (*)
- Mitigation of the negative effects of recycled aggregate water absorption in concrete technology, XVII ERMCO Congress, 4-5 June, Istanbul, Mathias Eckert, Miguel Oliveira (*)
- Risk of plastic shrinkage cracking in recycled aggregate concrete,: International Conference on Building Science and Engineering, 4-5 June, New York, Matthias Eckert, Miguel Oliveira (*)
- Quality assessment and classification of recycled aggregates from C&DW according to the European Standards, International Conference on Sustainable Design and Construction Engineering, 11-12 June, Copenhagen, M. Eckert, D. Mendes, JP. Gonçalves, M. Oliveira (*)
- Evaluation of the influence of early age shrinkage on the control of mortar cracking; Proceedings of EURO ELECS 2015, 21-23 July, Guimarães, Matthias Eckert, Miguel Oliveira, A. Bettencourt Ribeiro (*)
- (*) submitted







Our contribution may focus on: Recycled aggregate concrete - Self compacting concrete - Volume stability and cracking





Contacts:

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www.ualg.pt







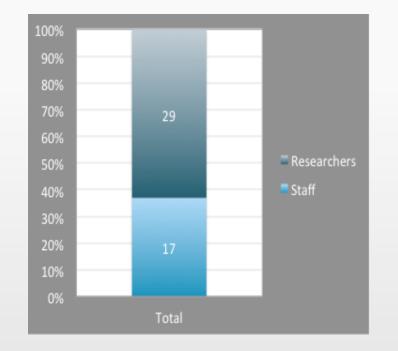




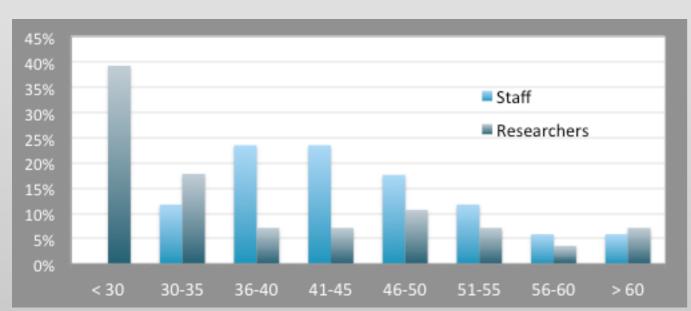


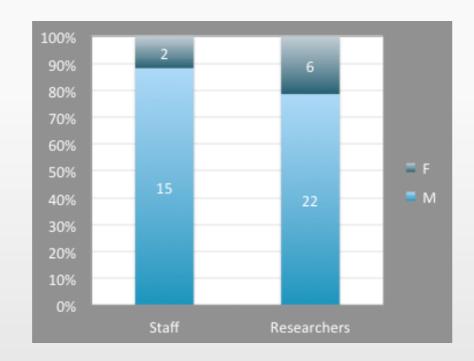
Civil Engineering Department

BASIC DATA OF INSTITUTION



Motivated and dynamic team International environment Integrated in international networks



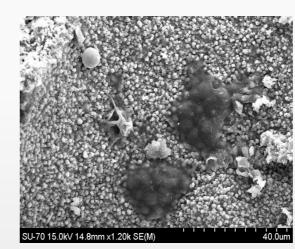


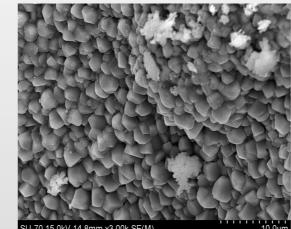
University: www.ua.pt

Department: www.ua.pt/decivil

Contact: Paulo Cachim pcachim@ua.pt

Materials engineering









Expertise in evaluation and analysis of building materials Mechanical and physical parameters Microstructural characterization Evaluation of binary/ternary compositions

Durability of building materials Chloride ingress

EQUIPMENT

Scanning Electron Microscopy (SEM) Thermogravimetric Analysis (TGA) X-Ray Diffraction (XRD) X-Ray Fluorescence (XRF)

Piezoresistivity Artificial ageing



Aerial view of Aveiro lagoon



Old town



Old town



Costa Nova beach



Campus view



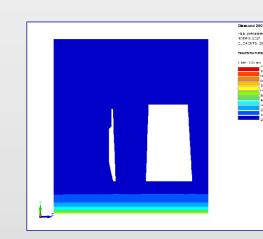
Civil Engineering building

Structural engineering

Evaluation of fire resistance of construction elements

Evaluation of the mechanical behaviour of structures and materials

Evaluation of cracking and retrofitting strategies Innovative structural solutions *In-situ* testing of structures









Software development Numerical modeling and analysis

EQUIPMENT

Vertical furnace – 3x3 m² Reaction wall and steel frames Actuators Measurement equipment

RISCO@DECivil

RISCO is the research unit of DECivil. It is a small unit, focused on three thematic lines:

Risks in the built environment

Construction sustainability

Built heritage conservation and restoration

Study programs

Doctoral program in Civil Engineering Specialization course in Risks and sustainable restoration

Integrated Master in Civil Engineering



Participation in several European and Portuguese research projects

Publications

Average 2.8 ISI articles/year/member (members have PhD degree) Average 5 concluded PhD/year

www.ua.pt/risco











RESEARCH PROGRESS ON REUSE OF FLUID CATALYTIC CRACKING WASTE

FROM OIL REFINERY IN CEMENT-BASED MATERIALS

CARLA M. COSTA

Department of Civil Engineering, High Institute of Engineering of Lisbon (ISEL), Lisbon, Portugal

FRAMEWORK

R&D PROJECT: ECO-ZEMENT, Reuse of Fluid Catalytic Cracking Waste from Oil Refineries In

Cement-based Materials (https://www.fct.pt/apoios/projectos/consulta/vglobal_projecto.phtml.en?idProjecto=113115&idElemConcurso=3556)

PRINCIPAL INVESTIGATOR: Carla M. Costa, ISEL

<u>FUNDING INSTITUTIONS</u>: Portuguese *Portuguese Foundation of Science and Technology & Portuguese oil company, PETROGAL.*

MOTIVATIONS

- Increase profits by turning a waste catalyst into a value added product
- Less discharged waste materials cost
- Novel cementitious materials with better performance including durability

ECONOMIC

TECHNOLOGICAL

ENVIRONMENTAL

- Less depletion of non-renewable raw materials from the quarries in cement plants
- Less energy consumption in cement plants
- Less CO2 emissions in cement plants
- Less solid waste production by oil industry

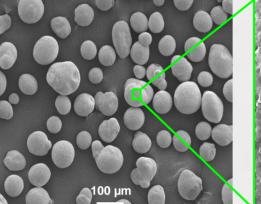
MOREOVER, IS IN LINE WITH:

- EU Waste Framework Directive (2008/98/EC): promote waste recycling and valorization
- the technological levers outlined by the "Cement Technology Roadmap" (WBCSD/IEA) to reduce CO₂ emissions of cement industry

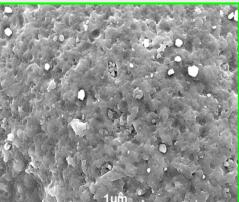
PORTUGUESE WASTE FLUID CATALYTIC CRACKING (wFCC) CATALYST



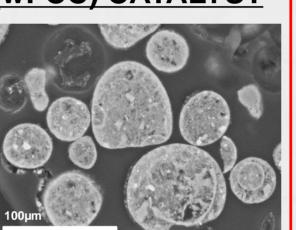




particles shape (SEM/SE image)



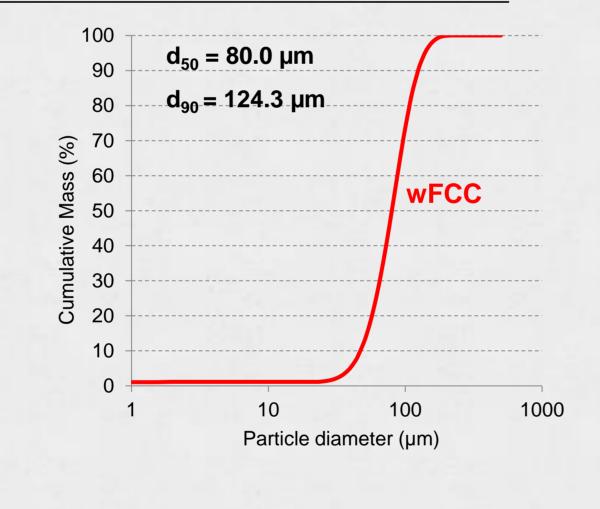
particle surface (SEM/SE image)



particles cross-section (SEM/BSE image)

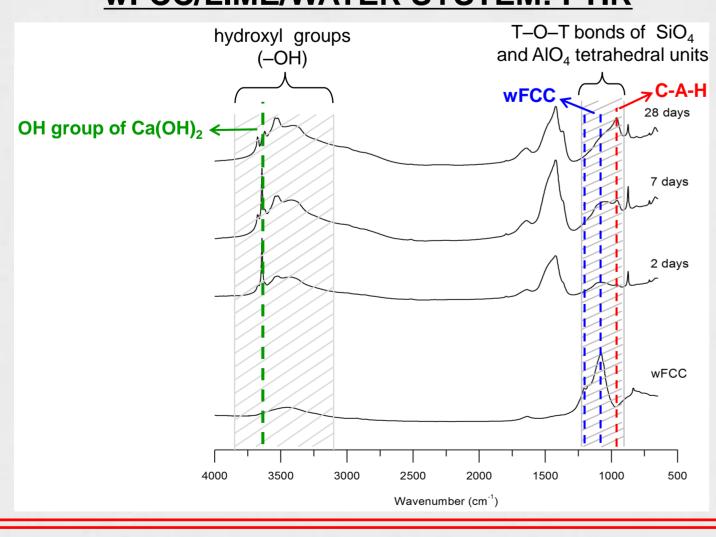
WFCC CHEMICAL AND PHYSICAL CHARACTERIZATION

Chemical analysis (% w/w)	
39.59	
52.81	
0.55	
0.09	
0.19	
0.23	
0.04	
0.68	
0.82	
0.06	
0.00	
0.00	
0.01	
1.49	
96.7	
	(% w/w) 39.59 52.81 0.55 0.09 0.19 0.23 0.04 0.68 0.82 0.06 0.00 0.00 0.00 1.49



- Specific gravity = 2.71 g/cm³
- Specific surface area = 150 m²/g
- Chapelle test: 1500 mg Ca(OH)₂
 consumed / g_{wFCC}

wFCC/LIME/WATER SYSTEM: FTIR

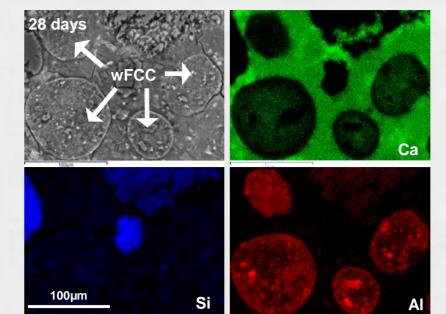


- [1] C. Costa, P. A. Carvalho, P. Marques (2012). Relationship Between Microstructure and Mechanical Properties of Binary Blended Cement Mortars

 Containing Waste Oil-Cracking Catalyst. ICDC 2012-International Congress on Durability of Concrete, Trondheim, Norway.
- [2] C. Costa, P. Marques (2012). Low-carbon Cement With Waste Oil-cracking Catalyst Incorporation. Cement Industry Technical Conference, 2012 IEEE-IAS/PCA 53rd San Antonio, Austin, USA.
- [3] C. Costa, M. S. Ribeiro, N. Brito (2014). Effect of Waste Oil-Cracking Catalyst Incorporation on Durability of Mortars. Materials Sciences and Applications 5: 905-914.
- [4] C. Costa, M. S. Ribeiro, N. Brito (2013). Concrete Repair Mortar Made of a Waste from Oil Refining Industry. Proceedings of the International Sustainable Building Conference Graz 2013. A. H. Passer, K; Maydl, P. Graz University of Technology, Graz, Austria, Verlag der Technischen Universität Graz: 1455-1462.

KEY RESULTS ON MORTARS WFCC INCORPORATION

SEM/BSE imaging & EDS analysis [1]



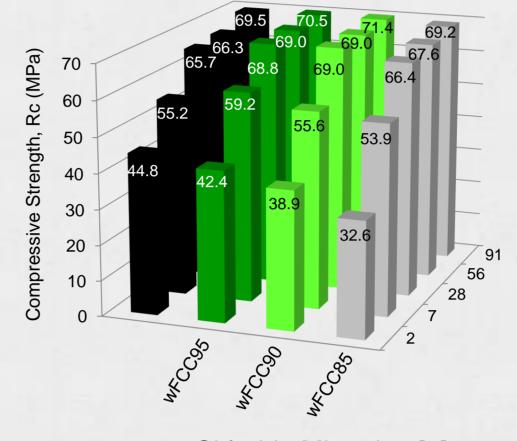
- wFCC particles incorporated in cementitious matrices:
- pozzolanic reaction occurs almost uniformly all over the wFCC particle's volume
- Ca diffusion front do not exist
- attributed to the three-dimensional internal structure of the zeolite



correlated with high pozzolanity reactivity of wFCC particles

Capillary Water Absorption [3]

Compressive Strength [2,3]

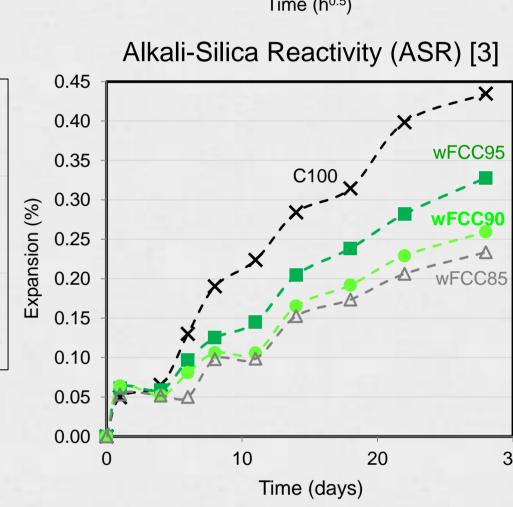


Mortar S (kg/m².h^{0.5})
C100 0.34
wFCC95 0.26
wFCC90 0.34
wFCC85 0.14

Legend: S – capillary absorption coefficient.

Chloride Migration [3]

(www. p. y. st. weight a series of the control of the con



<u>Legend of Figures</u>: C100 — Plain cement mortars (used as reference)

wFCCx— wFCC blended cement mortars where x represents the mass replacement percentage of cement with wFCC catalyst

TECHNOLOGYCAL APPLICATIONS

EU standards

(which requirements are met)

• CEMENT INDUSTRY

- ✓ as a cement main constituent [2]
- EN 197-1 (Common cements composition and specifications)

CONSTRUCTION MATERIALS INDUSTRY

- ✓ as addition for mortars [4]
- EN 1504-3 (Concrete repair mortars)
- Currently under evaluation: EN 998 (Rendering and plastering mortar)
- ✓ as addition for concrete [5,6]
- EN 206-1 (Concrete specifications)
- EN 206-9 (Self-Compacting Concrete (SCC) specifications)
- ✓ alkali-activated mortars from the wFCC catalyst [7]

MAJOR FIDINGS

wFCC is generated in significant amount worldwide: 500 kton/year

&

- scientific and technologycal results revealed that wFCC catalyst has potential
- ✓ For industrial large-scale application
- ✓ To become a steady supply for construction materials industry
- [5] M. Antunes (2013). ECO-Concrete with Addition of a Waste from Oil Refinery (in Portuguese). MA thesis, Instituto Superior de Engenharia de Lisboa, Lisboa, Portugal.
 [6] J. L. António, P. Raposeira Silva, C. Costa (2013). Fresh Properties and Compressive Strength of Self-Compacting Concrete Containing Waste Fluid Catalytic Cracking Catalyst. 7th RILEM International Conference on Self-Compacting Concrete and 1st RILEM International Conference on Rheology
- and Processing of Construction Materials. 1-6 September, Paris, RILEM Publications SARL.
 [7] C. Costa, C. Ferreira, M. F. Ribeiro, A. Fernandes (2014). Alkali-Activated Binders Produced from Petrochemical Fluid Catalytic Cracking Catalyst Waste. IJRET: International Journal of Research in Engineering and Technology 3(13): 114-122.









UNIVERSITY OF NOVI SAD - **SERBIA** - FACULTY OF TECHNICAL SCIENCES



DEPARTMENT OF CIVIL ENGINEERING AND GEODESY

Prof. dr Vlastimir Radonjanin, Prof. dr Mirjana Malešev Ivan Lukić, Vesna Bulatović



RECENT RESEARCH PROJECT: GREEN RECYCLED AGGREGATE CONCRETE



Demolishing of RC

structure



Demolished concrete waste

Fine river

aggregate



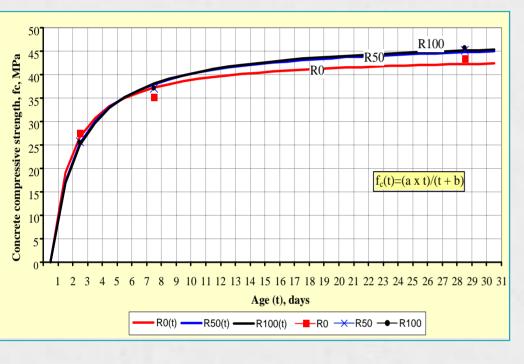


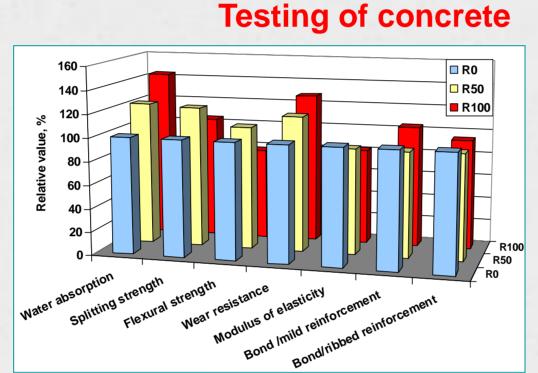
RCA 4-8mm

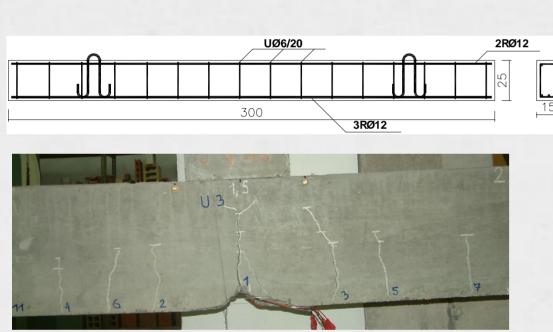
RCA 8-16mm

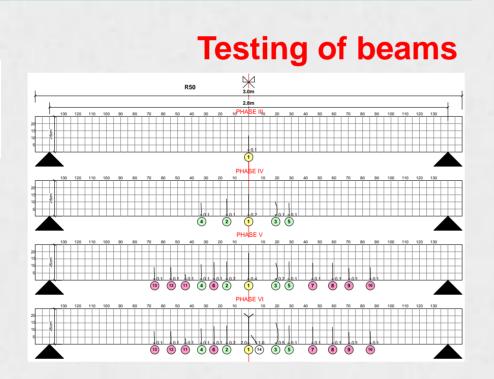
I Phase

STRUCTURAL CONCRETE WITH RECYCLED CONCRETE **AGGREGATE**





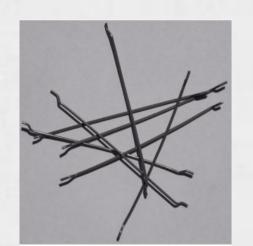




II Phase

FIBER REINFORCED RECYCLED AGGREGATE CONCRETE

Concrete type	NO	NF (fiber)	RO	RF (fiber)
f _{comp} , MPa	33,0	31,9	27,6	26,9
f _{flex} , MPa	7,0	11,2	6,1	10,0
E, GPa	32,0	30,0	26,0	25,5





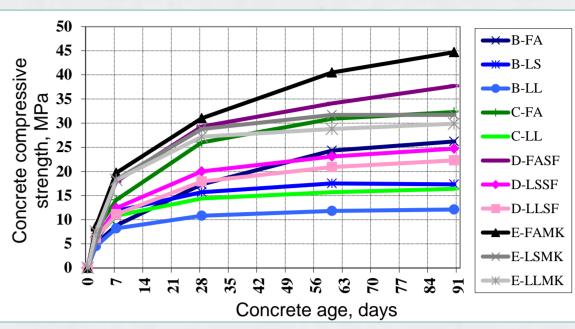


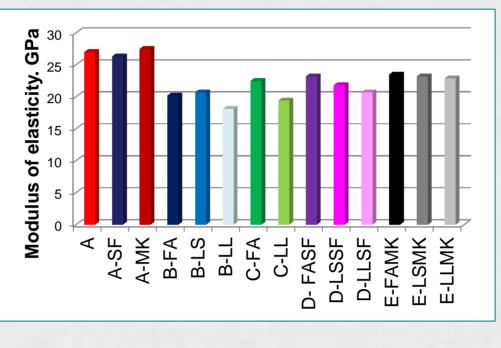
III Phase

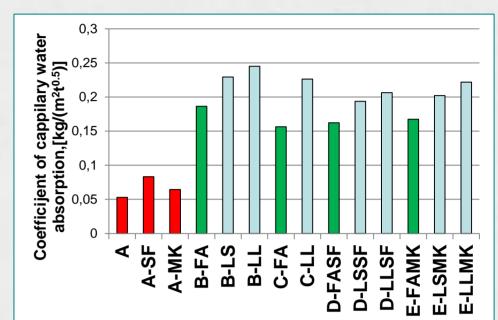
BASIC PROPERTIES OF RAC WITH HIGH VOLUME OF DIFFERENT MINERAL ADMIXTURES

MINERAL ADMIXTURES: fly ash, limestone, metacaoline, silica fume









IV Phase

DURABILITY OF HIGH STRENGTH RAC WITH FLY ASH AND LOW WATER-CEMENT RATIO

Concrete	Referent samples		RAC (30%FA)			RAC (50%FA)			
type	E1	E2	E 3	R11	R12	R13	R21	R22	R23
w/p	0.543	0.4	0.3	0.543	0.4	0.3	0.543	0.4	0.3
w/b,eff	0.543	0.4	0.3	0.63	0.46	0.35	0.72	0.53	0.4
f _{c,28} (MPa)	41.6	52.7	68.5	38.6	49.6	64.7	36.1	47.9	62.3

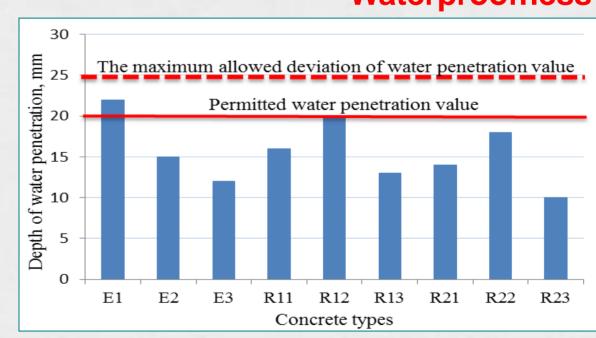
Chloride ion penetration





Waterproofness





V Phase (IN PROGESS)

DURABILITY OF RAC - SULPHATE RESISTANCE

List of selected scientific/research papers related to the COST action TU 1404

Malešev, M., Radonjanin, V., Lukić, I., Bulatović, V. (2014): The effect of aggregate, type and quantity of cement on modulus of elasticity of lightweight aggregate concrete, Arabian Journal for Science and Engineering, Volume 39, No. 2, 705-711.

Radonjanin, V., Malešev, M., Marinković, S., Al Malty, A.: Green recycled aggregate concrete, Journal "Construction and Buliding Materials", Vol. 47, October 2013, pp. 1503-1511.

Marinković, S., Ignjatović, I., Radonjanin, V., Malešev, M. (2011): Recycled Aggregate Concrete for Structural Use-An Overview of Technologies, Properties and Applications, Innovative Materials and Techniques in Concrete Construction, Springer, pp. 115-130.

Marinković, S., Radonjanin, V., Malešev, M. (2011): Utilization of recycled Waste Concrete Aggregates in Structural Concrete, Recycling: Processes, Cost and Benefits, Nova Science Publishers, Inc., New York, pp. 313-344, 2011.

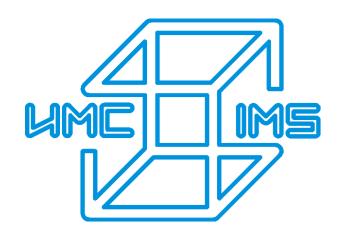
Malešev, M., Radonjanin, V., Marinković, S.: Recycled Concrete as Aggregate for Structural Concrete Production, J. Sustainability 2010, 2(5), pp.1204-1225. Marinković, S., Radonjanin, V., Malešev, M., Ignjatović,I.: Comparative environmental assessment of natural and recycled aggregate concrete, Waste Management, 2010, Vol. 30, No. 11, pp. 2255-2264.











IMS INSTITUTE - SERBIA

Ksenija Jankovic PhD, Dragan Bojovic MSc, Marko Stojanovic MSc, Ljiljana Loncar

CONCRETE WITH RECYCLED BRICK AS AGGREGATE

The investigation included concrete made by using recycled brick as aggregate. Experimental work included several types of concrete made with the same cement content (385 kg/m³), and same consistency (slump about 1 cm). Recycled brick and combination of natural river aggregate and recycled brick were used as aggregates. Comparing previous test results of concrete paving blocks and tiles made of ordinary concrete and properties of concrete with recycled brick as aggregate it can be concluded that this kind of concrete can be used for production of elements for pedestrian areas and various non-structural elements in the area with continental clime.





Figure 1. Crushed brick-fractions 0/4 and 4/8mm

	_			10.0
		OCT	resu	

Concrete / Percent of recycled bricks	Water absorption % by mass	Mass loss after freeze/thaw test kg/m²	Bending strength for concrete flags MPa	Tensile splitting strength T for concrete blocks MPa	Abrasion resistance cm ³ /50cm ²
P2/100%	20.4	0.008	2.6	2.2	24.64
P3/60%	13.1	0.005	4.5	3.2	16.76
P4/25%	8.6	0.0	5.1	4.5	12.47
P5/50%	11.7	0.0	4.2	3.2	12.49
P6/65%	13.5	0.020	3.8	2.5	15.18
P7/32.5%	8.4	0.0	5.8	5.3	12.18





Figure 2. Concrete with 100% of recycled bricks aggregate and Concrete with combination of river and crushed bricks aggregate Table 2 Experimental results

	Concrete mix				
Testing	P1-ref.	P2	P4	P6	P7
Density of hardened concrete (kg/m³)	2356	2008	2288	2129	2254
SRPS U.M1.055 (degradation degree)	1	0	0	0	0
Compressive strength (MPa)	53.2	38.7	57.4	40.0	57.6
Spacing factor (mm)	0.18	0.029	0.046	0.045	0.054
Rapid Air 457 (% of air)	5.2	23.6	10.6	15.4	14.5
Entrained air in concrete (%)	2	4.1	3.9	2.5	4.5

Janković, K., Nikolić, D. and Bojović, D. (2012): "Concrete paving blocks and flags made with crushed brick as aggregate", Construction and Building Materials, Vol. 28, pp. 659-663

ULTRA HIGH STRENGTH CONCRETE

Possibilities of getting UHSC designed with the materials that are available in Serbian market were tested in the experimental work. Steel fibers were used: length 8mm, diameter 0.175mm. Four series of samples were made with different types of fine reactive additives (silica fume -SF in referent concrete was replaced with metakaolin-MK at 20% and 40% and with fine fly ash-GFA at 20%.

Table 1. Curing regime

Cure code	Cure type
SC95/24	24 h 95°C steam cure
SC95/48	48 h 95°C steam cure
AC8/4	4 h 8 bar autoclave
AC20/4	4 h 20 bar autoclave

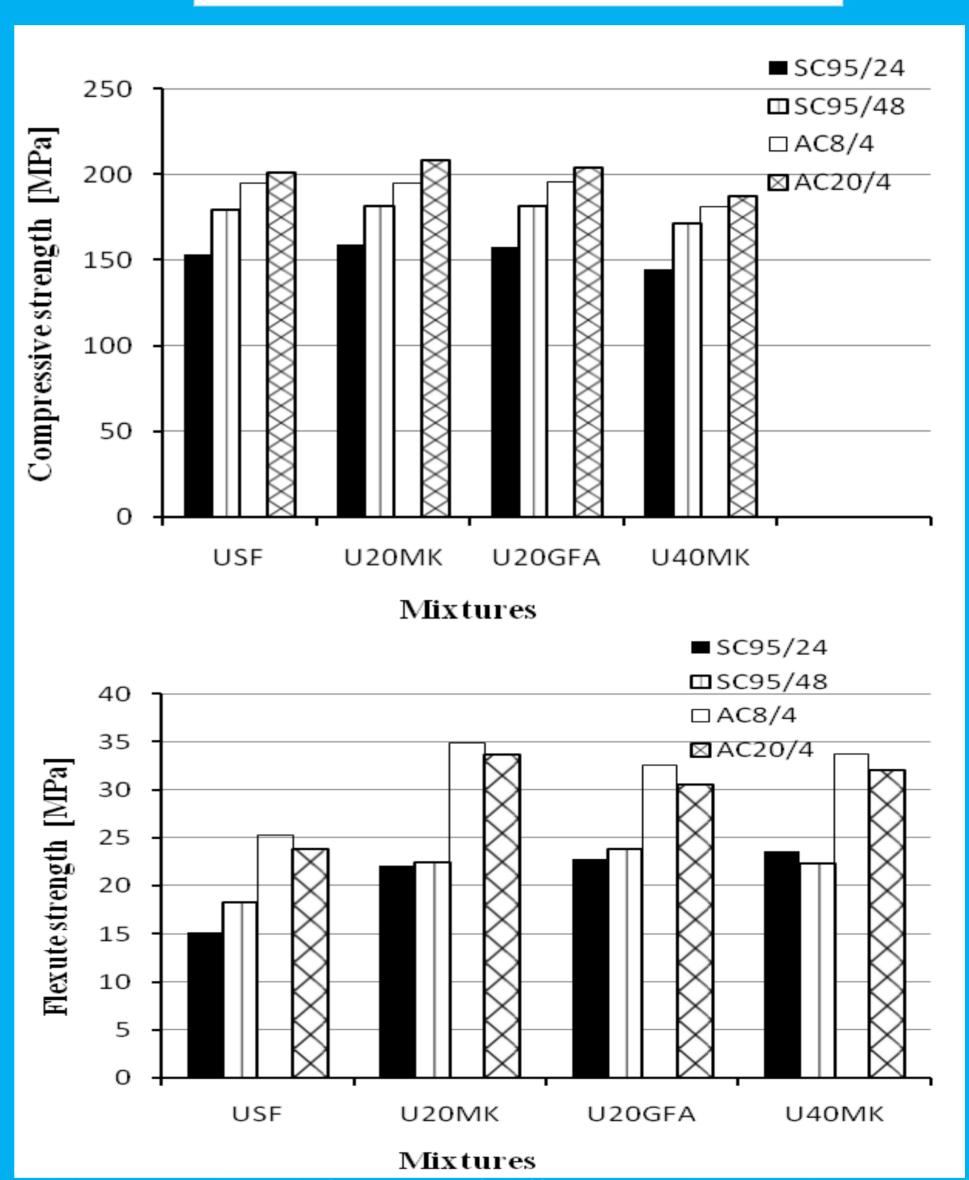


Figure 1. The influence of different curing regimes on compressive strength and flexure strength

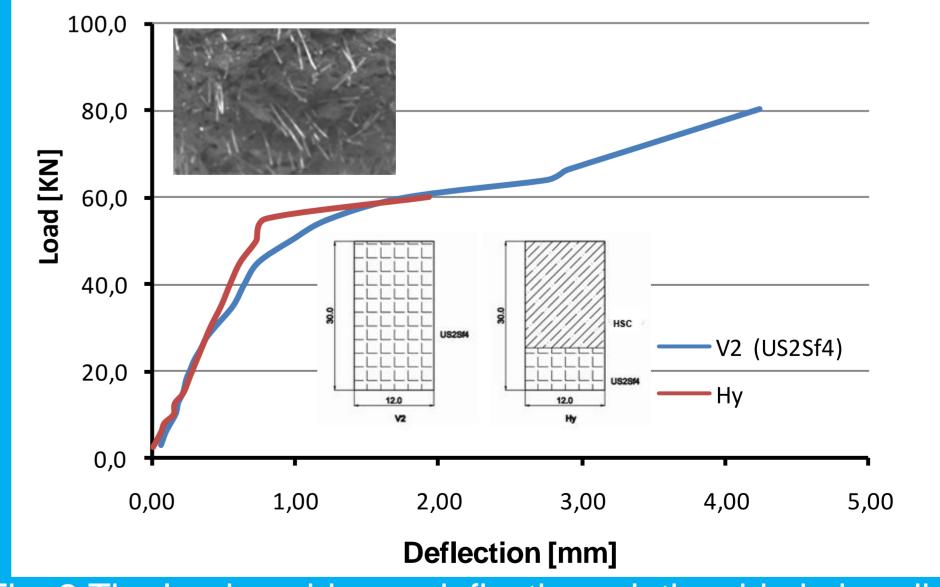


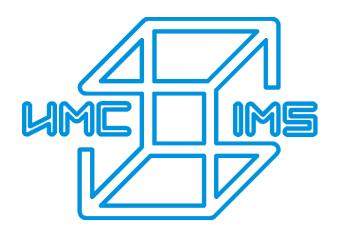
Fig. 2 The load – midspan deflection relationship in bending test Jankovic, K., Cirovic, G., Nikolić, D. and Bojović, D. (2011): "Mechanical properties of ultra high properties self compacting

concrete with different mineral admixtures", Romanian Journal of Materials, Vol. 41, No.3, pp. 211-218









IMS INSTITUTE - SERBIA

Ksenija Jankovic PhD, Dragan Bojovic MSc, Marko Stojanovic MSc, Ljiljana Loncar

APPLICATION OF NEURAL NETWORK ON CONCRETE PROPERTIES

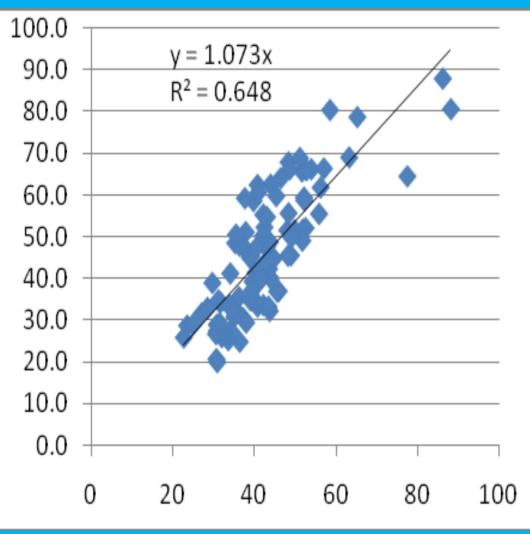
Soft programming techniques especialy neural networks and the formation of databases related to the testing in laboratories for concrete opened up new approaches in predicting the impact of the quantity of entrained air in concrete on compressive strength. The database was formed based on previous laboratory tests of concrete in the IMS Institute on the period 2009-2011 years. During this period conducted a laboratory trial mix of concrete with cements from 3 different producers from the territory of Serbia. There were 3 types of cement CEM II A/S, CEM II A/M(S-L), CEM II B/M(S-L) and all cements were strength class 42.5. Mass of cement per cubic m of concrete was in range of 250 to 500 kg. As the aggregate were used in all concretes river aggregate from Serbia. Data processing was performed in two stages. In first stage, database was considered with classical approach with formula:

$$f = \frac{A_0}{B_0^{w/c}} \times 10^{0.038 \times a}$$

and values of 180 for A₀, 20 for B₀.

Table 1. Results obtained with different approach

	Standard deviation of error (N/mm²)	Accuracy at reliability of 95.4% (N/mm²)
Classical Approach	8.8	17.6
Neural Network Approach	4.4	8.8



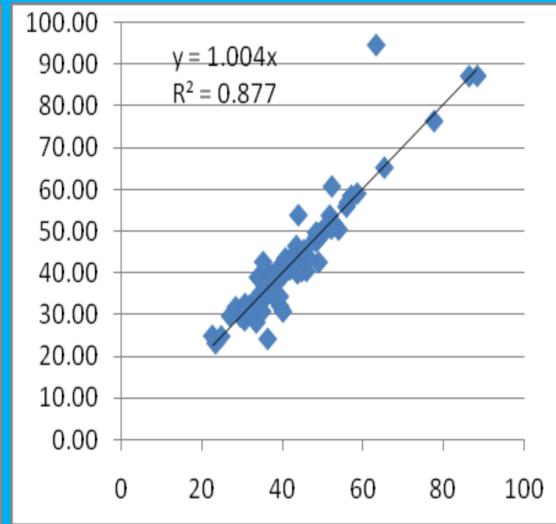


Figure 1. Classical approach Figure 2. Neural network approach

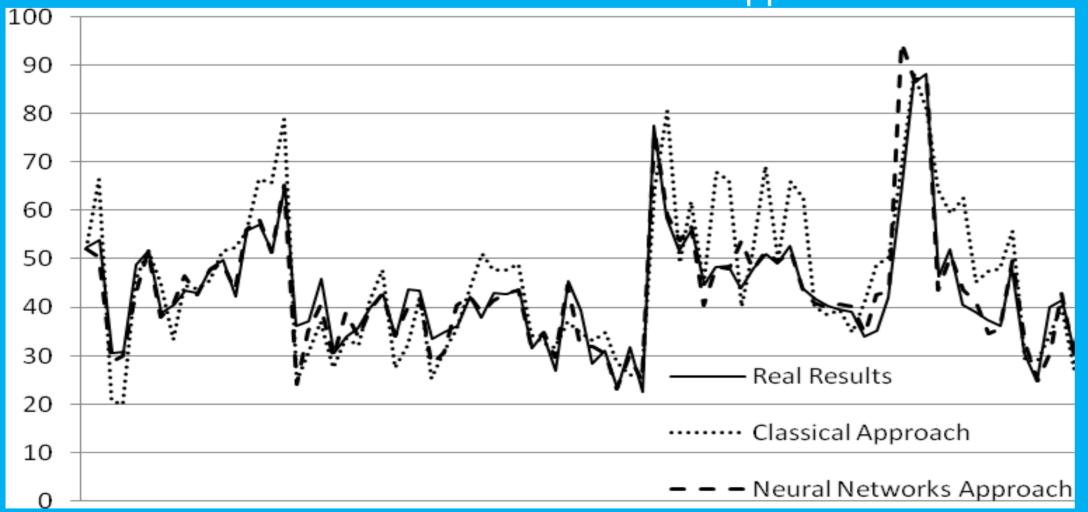


Figure 3. Diagram of all results

Bojović, D., Nikolić, D., Janković, K., Lončar, Lj. (2012): "Evaulation of air content on concrete compressive strength with classical approach and neural networks", Building Materials and Structures, Vol. 55, No. 1, pp. 47-54

DURABILITY OF CONCRETE WITH DIFFERENT TYPES OF CEMENT

Resistance to corrosion caused by sulphate, nitrate, carbamide, lactic acid and acetic acid was presented. Optical and scanning electron microscopy (SEM) was used to examine the effect of aggressive solutions on the microstructure and mechanical properties of mortar. The chemical resistance of mortar prisms and two types of concrete were tested according to the Koch-Steinegger method. As the condition for resistance in aggressive solution is that flexural strength of mortar prisms is no less than 70 % compared to referent prisms cured in water it can be concluded that mortar and concrete made with CEM III/B in this investigation are resistant to all treated acids.

The specimens were made by using cement CEM III/B 32.5 N – LH/SR (20 - 34 % Portland cement clinker and 66-80 % additions of slag).

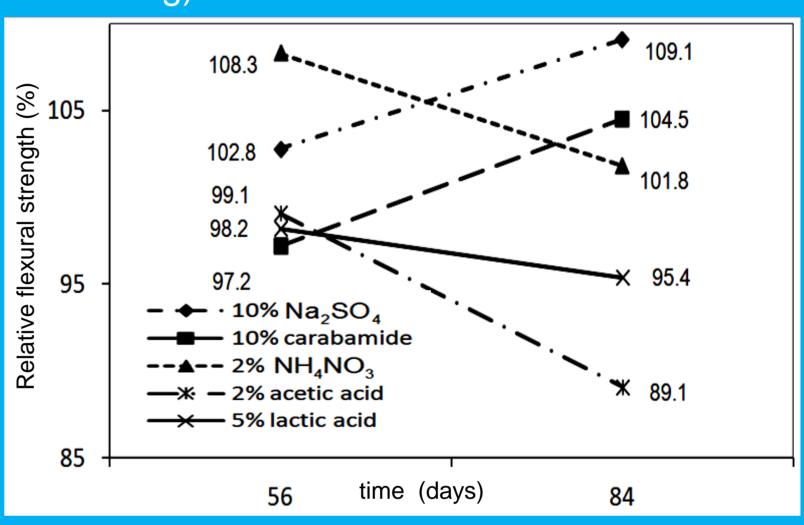


Fig 1. Relative flexural strength of mortar vs. time in aggressive solution

Component materials that are available in Serbian market are used for this part of work. Previous trials confirmed their compatibility. Water that is used for mixture production is potable water. Two mine types (five types) of cement were used in this part of work:

Cement 1:CEM II/B-M (L-V) 42.5 R, \rightarrow (Concrete Series **A**) Cement 2:CEM I 42.5 R, \rightarrow (Concrete Series **B**) Cement 3:CEM II/A-S 42.5 N \rightarrow (Concrete Series **C**) Cement 4:CEM II/A-M (S-L) 42.5 R \rightarrow (Concrete Series **D**) Cement 5:CEM II/B-M (S-L) 42.5 R, \rightarrow (Concrete Series **E**)

Table 1. – Experimental results

	Conorata					Co	ncret	e ser	ies				
	Concrete	Seri	es A	Serie	es B		Serie	es C		Seri	es D	Serie	es E
1	testing	A1	A2	B1	B2	C1	Z 2	C2	X2	D1	D2	E1	E 2
	Water reduction	_	12.2	_	11.6	_	17.4	12.8	12.8	_	10.5	_	12.2
	(%)												
	Air	4.0	4.0	4.0		4.0	0.4			4.0			
	content (%)	1.6	4.2	1.8	5.1	1.8	3.4	5.2	5.0	1.8	3.3	2.0	4.5
	Consiste												
	ncy (cm)	2.5	2.5	3.5	3.5	4.5	4.5	14.5	13.5	2.5	2.5	5.0	5.0
	Degree of	3	2	0	0	1	0	0	0	0	0	1	1
1	damage												'
	Class of frost resistance	M- 250	M- 250	M- 250	M- 250	M- 250	M- 250	M- 250	M- 250	M- 250	M- 250	M- 250	M- 250

Janković, K., Bojović, D., Stojanović, M i Lončar, Lj. (2014): "Resistance of CEM III/B based materials to acid attack", Building Materials and Structures, Vol. 57, Br. 2,pp. 29-37











Považská cementáreň, a. s., Ladce

----- since 1889 -----

APPLIED RESEARCH AND DEVELOPMENT PROJECT ON NONSTANDARD CONCRETE VOLUME STABILITY TESTING

draft

place of R&D project: Pov

Považská cementáreň, a.s., Ladce

duration of project:

2 - 3 years

number of researchers:

1 senior researcher with assistance of skilled laboratory staff

budget:

to be discussed

materials:

CEMENTS PRODUCED ACCORDING EN 197-1

CEMI	CEM II	CEM III
42,5N, 42,5R, 52,5 R	32,5 R, 42,5 N, 42,5 R	32,5 N

NEW GENERATION CEMENTS

H-©EMENT		CH/MPI/N
Shrinkage reducing cement	Sulphateresisting cement	Ultrahighperformance cement

Equipment of industrial and applied R&D laboratory is described in poster 1.

The aim of R&D project will be to evaluate properties mainly volume stability of concrete based on improvement of existing techniques and/or nonstandard ones.

There are some advanced testing methods in thoughts:



- 1. Existing laser beam monitoring of dilatation and temperature could be extended by measurement of moisture and calculation of volume changes of hardened concrete.
- 2. Testing of concrete volume stability in cylinder mould Ø 150 mm/300 mm at 28 days strength. If there will be shrinkage concrete sample is removed without destruction.

 Same concrete design is tested with mould at 28 days strength.
- 3. Concrete is tested in same mould as in B and fitted with smooth rebar Ø 25 mm for pull out at 28 days, this is demo of volume stability too.



CONCRETE MIXES COULD BE PREPARED UNDER HIGHER TEMPERATURES IN SPECIAL MIXER

RECENT OWN R&D PROJECTS

New generation of cements 2009 – 2014.

Papers related to COST TU 1404.

Strigáč, J., Martauz, P., "Novel hybrid cement based on different mechanisms of setting and hardening", Proceedings of RILEM International Workshop on Performance-based Specification and Control of Concrete Durability, 11 – 13th June 2014, Zagreb, Croatia;

Janotka, I., Bačuvčík, M., Martauz, P. and Strigáč, J., "Chemical resistance of novel hybrid cement in various aggressive solutions", Proceedings of RILEM International Workshop on Performance-based Specification and Control of Concrete Durability, 11 - 13th June 2014, Zagreb, Croatia.

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Correlation of rheological parameters of fresh



concrete and mortar mixtures with time

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Abstract

A measuring of rheological properties of fresh concrete is more and more important, especially when following development of these properties with time. However, much more material is needed when dealing with concrete properties when compared with mortar properties. Therefore, the aim of this study was to reduce the number of concrete batches needed to assess the time development of concrete properties on the basis of the results of rheological tests made on mortar mixtures which composition is deduced from the concrete composition. To establish a link between mortar and concrete mixtures, all the measured rheological values were normalized with respect to the initially measured value. **Key words**: concrete, fresh, mortar, rheology, plastic viscosity, time, yield stress.

1 Definitions and assumptions

- The basic definition of rheology is "It is a science of deformation and flow of matter". It deals with relationships between stress, strain, rate of strain and time. Rheology gives fundamental physical quantities which are not dependent on particular apparatus or geometry of apparatus [1].
- We consider **fresh** ordinary concrete and mortar.
- Bingham model [1].
- ConTec Viscometer 5 with two different measuring systems.

2 Materials

- Cements CEM II/A-M (LL-S) 42,5 R and CEM I 42,5 R.
- · Crushed limestone aggregate.
- Chemical admixtures (polycarboxylate SP, air entrainer-AE, viscosity agent-VA).
- Mineral additives (natural zeolite tuff, silica fume-SF, slag-GGBS).

3 Mixture proportioning

Basic mixture for concrete: cement 400 kg 953 kg fine aggregate coarse aggregate 0,50 W/C_{ef} 212 kg water

Chemical admixtures were added and cement was replaced with mineral additives in different combinations

Mortar mixtures were prepared on the basis of these concretes with **CEM method**. The principle is that we replace coarse aggregate with fine aggregate in such a way that a surface area of fine aggregate in mortar is the same as the surface area of total aggregate in concrete [2].

4 Expected CEM flow table spread

We compare flow table spreads of mortars to the expected spreads of mortar. The expected spread of CEM mortar was calculated on the basis of measured spread of concrete. Spreads were normalized with a diameter of the base of the cone as it is described in the equation below:

$$\frac{d_{\text{exp.mortar}}}{100} = \frac{d_{concrete}}{200} \rightarrow d_{\text{exp.mortar}} = \frac{d_{concrete}}{2}$$

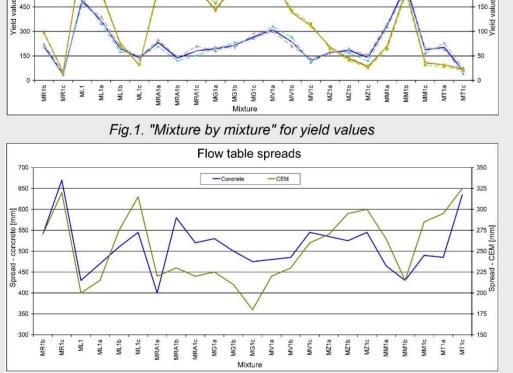
5 Test procedure

- Mixing,
- flow table spread for concrete or mortar according to, respectively EN 12350-5 and EN 1015-3,
- parallel to workability tests we tested mixtures on the rheometer,
- we measured properties at times* 0 minutes, 20 minutes, 40 minutes and 60 minutes after mixing was finished.

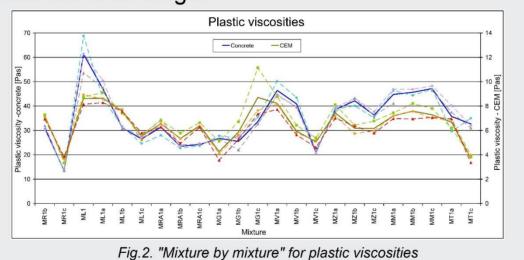
6 Results

"Mixture by mixture" comparison

At time 0 minutes, dashed lines are repetitions, solid line is average.



Yield values

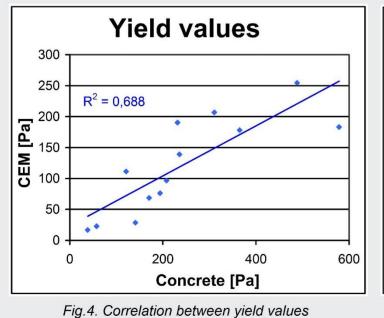


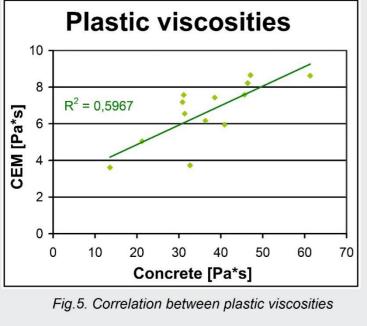
- no problems with repeatability
- deviations for some mixtures
- same mixtures deviate in yield values and flow
- table spreads
- mixtures with AE and VA

Correlation between concrete and CEM

Fig.3. "Mixture by mixture" for flow table spreads

At time 0 minutes, before and after elimination of certain results. The criterion for removal is: difference between CEM flow table spread and expected CEM flow table spread is 30 mm or bigger.

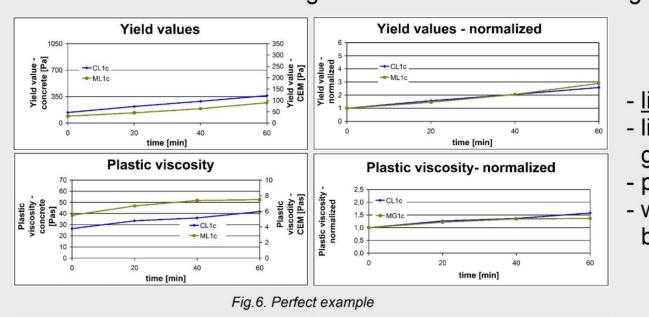




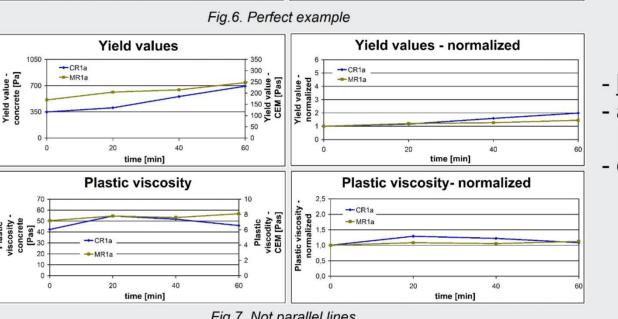
- bad correlation between yield values
- correlation got better after the elimination of certain results

Correlation between concrete and CEM with time

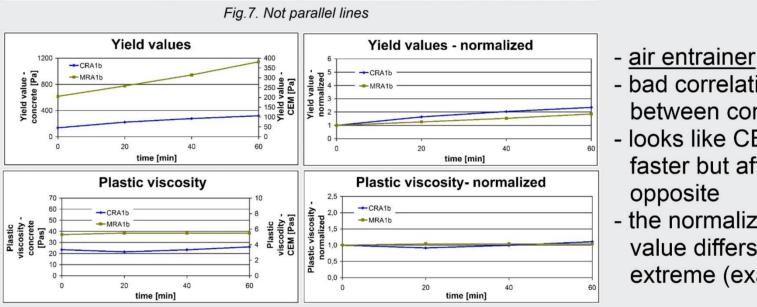
The results are shown in original and normalized values regarding to the value at time 0 minutes.



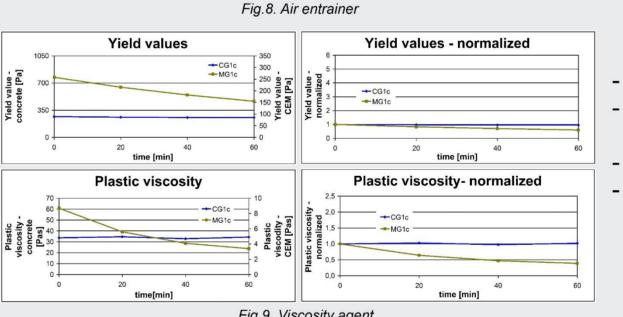
- lines are parallel
- lines cover each other in normalized graphs
- perfect example
- we can predict concrete behaviour on the basis of CEM measurements



- lines are not parallel (viscosity) - after the normalization we see similar time behaviour for concrete and CEM
- comparison is possible

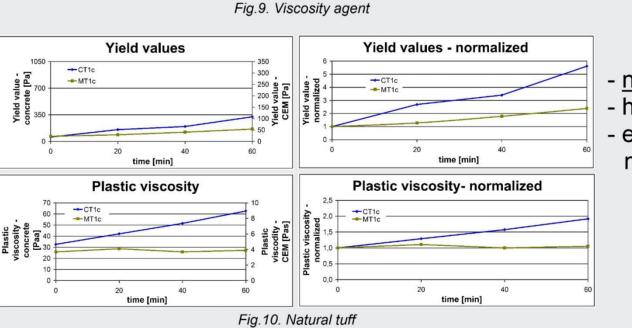


- bad correlation for initial yield values between concrete and CEM
- looks like CEM yield value is growing faster but after the normalization it is the
- the normalization is sensitive if initial value differs from the expected or is extreme (example 0 Pa)



viscosity agent

- its influence on CEM is totally different than on concrete
- CEM has no coarse aggregate - VA loses it's effect with time



- natural tuff - high SP demand

- excess of SP in CEM because we have no coarse aggregate

7 Conclusions

- "Mix by mix" comparison shows that some results deviate from the expected behavior.
- Additional criterion for suitable results was created, the expected CEM flow table spread. On this basis we eliminated some results. The correlation was much better than the correlation of basic results.
- Mixtures with AE, VA and tuff are not fully appropriate for comparing time behavior of concrete and CEM, unless we find some kind of modification to the CEM method.
- CEM flow table spreads should be closer to the expected spreads.
- Suggestions for modifying CEM method are that for the mixtures without SP we should adjust water content, for mixtures with SP we should adjust SP amount similar to the method described in literature [3]. For other problematic mixtures similar actions should be made to adjust the additive that has the most distinct influence in how the mixtures behave.

References

[1] Tattersall, G.H., Banfill, P.F.G.: The rheology of fresh concrete, First edition, Pitman, Boston, London, Melbourne, 1983.

[2] Schwartzentruber, A., Catherine, C.: Method of the concrete equivalent mortar (CEM) - A new tool to design concrete containing admixture, Materials and Structures, 33 (2000) 232, pp. 475-482. [3] Erdem, T.K., Khayat, K.H., Yahia, A.: Correlating Rheology of Self-Consolidating Concrete to Corresponding Concrete-Equivalent Mortar, Aci Materials Journal, 106 (2009) 2, pp. 154-160









DETERMINATION OF EARLY AGE PROPERTIES OF CEMENT BASED MATERIALS USING FREQUENCY SPECTRUM OF ULTRASONIC P-WAVES

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- ² Slovenian National Building and Civil Engineering Institute, Dimičeva 12, 1000 Ljubljana, email: matija.gams@zag.si

1. Introduction and objectives

During the last decade, a comprehensive research has been performed with the objective to develop a procedure based on ultrasonic (US) P-waves used to determine various properties of cement based materials (CBMs) [1-7]. A methodology based on a proper analysis of frequency spectrum of US P-waves has turned out to be the most convenient, effective, accurate, and reliable. Using this approach, one can easily and accurately determine, monitor analyse various important that during milestones appear solidification process of CBMs, such as

initial and final setting time [3,5], different periods during setting process, onset early age development of compressive strength [7], etc. The procedure is fully automated, nondestructive, continuous and easy to operate and can be effectively used for any type of CBMs, i.e. cement pastes, mortars, and concretes, regardless of the material's composition.

The main objective of the project is to develop a prototype of US instrument together with a user-friendly PC software based on the results of the experimental work.

2. Materials and methods

Many CBM mixtures which differed in their w/c ratio, curing temperature, and basic materials were prepared to test the ability of the procedure to determine different properties of CBMs. For this purpose, various cement types with different amount of clinker and different fineness, different amount, shape, type, and size of aggregates, and different types of chemical and mineral admixtures were used.

At first, a commercially available US instrument was used to perform US measurements, consisting of a main unit and two (150kHz) resonant type transducers (fig. 1).

At every time step, velocity of US longitudinal waves v_P through the test material, spectral analysis of the received US signal using FFT technique, material's and temperature were determined. Supplementary methods were done

to obtain different

characteristics

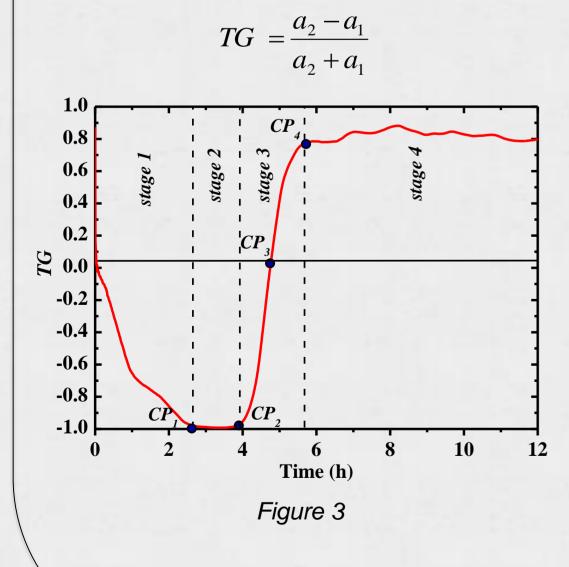
CBMs

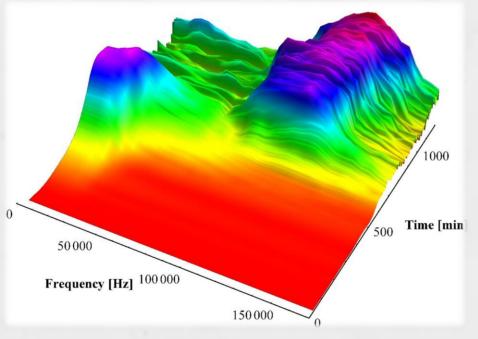


Figure 1

3. TG parameter

A new US parameter, called parameter has been developed and calculated at every time step, dimensionless representing ratio between maximum amplitudes a_1 and a_2 of low (f_1) and high (f_H) dominant frequency ranges, respectively, that appear in the frequency spectrum of US P-waves (fig. 2) [3]:





of

Figure 2

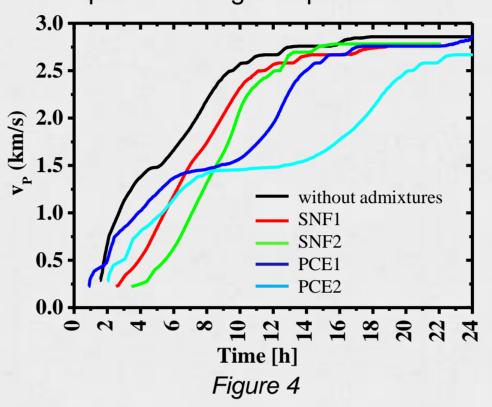
When concrete is still a fluid-like suspension, only low frequencies get through the material and high frequencies are completely damped. During this stage, only the peak (a₁) in the low frequencies of the frequency spectrum can be observed. With the ongoing hydration, the peak (a_2) at high frequencies gradually appears [3]. Automatic calculation of TG parameter at every time step gives a unique TG - tcurve for every material. However, all the curves have similar shape shown in fig. 3, indicating 4 characteristic stages and 4 characteristic points.

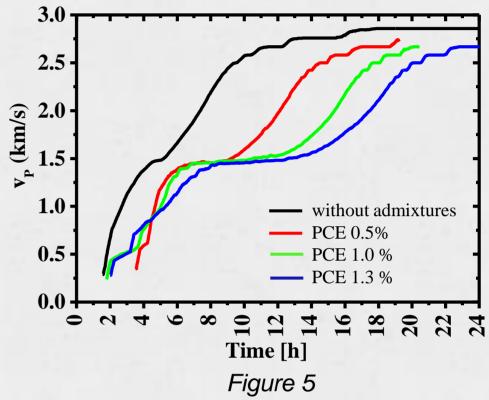
4. Results

THE USE OF US TECHNIQUE TO STUDY THE INFLUENCE OF DIFFERENT BASIC MATERIALS ON THE FORMATION OF STRUCTURE PROCESS

US technique is effective in evaluating influence of basic materials on the solidification of CBMs [6], e.g. to study working principles of superplasticizers [4]. In the case of PCEs, the plateau occurs when the v_P reaches the velocity in water, indicating retardation of the development of the connected solid phase during this period. On the

contrary, uniform development of the microstructure was observed when sulfonate naphthalene-formaldehyde (SNF) SPs were used (fig. 4). The length of the plateau on the $v_P - t$ curve increases with increasing dosage of PCE and is inversely proportional to the surface area of the hydration products (fig. 5).





THE ABILITY OF TG PARAMETER TO INDICATE SETTING TIMES

Using TG parameter, initial and final setting times can be determined accurately. Setting period corresponds to stage 3 on the TG - t curve (fig. 3) and initial and final set correspond to

points CP₂ and CP₄, respectively, regardless the material's of composition (i.e. presence aggregates, etc., fig. 6) [5].

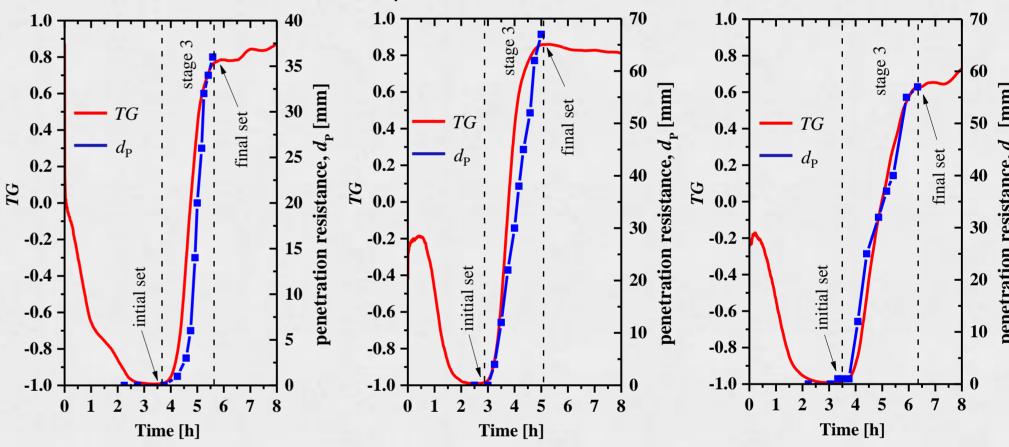
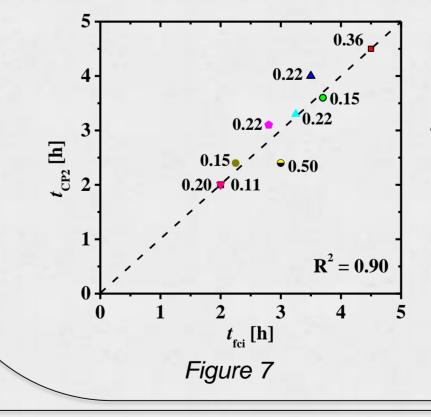


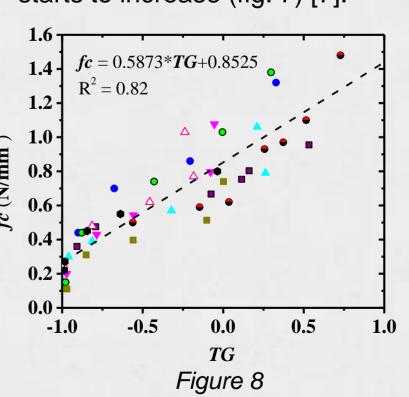
Figure 6: cement paste (left), mortar (middle), and concrete (right)

THE ABILITY OF TG PARAMETER TO INDICATE ONSET AND INITIAL **DEVELOPMENT OF COMPRESSIVE STRENGTH**

Using TG parameter, onset t_{fci} and initial development of compressive strength can be accurately determined, regardless of the CBM's composition. Both compressive strength and TG develop according to similar trend during the first three

stages on the TG - t curves (fig. 8). The first significant increase in early age compressive strength occurs approximately at the beginning of the third stage (t_{CP2}) on the TG - t curve, i.e. at the time when TG parameter starts to increase (fig. 7) [7].





6. References

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- based materials. Cement and Concrete Research, (2015),67,p.148-155.









Monitoring water penetration in hardened concrete by means of nondestructive techniques: INFRARED THERMOGRAPHY AND GROUND-PENETRATING RADAR

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POSTER 2

Concrete is a porous material and this implies that through the pores network aggressive substances dissolved in water can penetrate inwards. Consequently, the durability of reinforced concrete structures depends mainly on the pore structure and the level of cracking, as well as on its water content. Currently, some nondestructive techniques, such as infrared thermography (IR) and ground-penetrating radar (GPR), are providing very promising and interesting results characterizing and assessing the variation of concrete properties.

This research project is focused on study of the durability control by analyzing the evolution of electromagnetic waves parameters while water penetrates inward in hardened concrete. Specifically, it is very interesting to study in detail the behavior of this material when a waterfront penetrates inward, using the electromagnetic field generated with a commercial GPR antenna or recorded with a commercial IR Camera. The free water content has a decisive influence on the dielectric properties of concrete. Therefore, changes in wave parameters will occur as a result of the advance of the waterfront and might provide reliable information, both qualitative and quantitative, about how this water penetration occurs.

Keywords

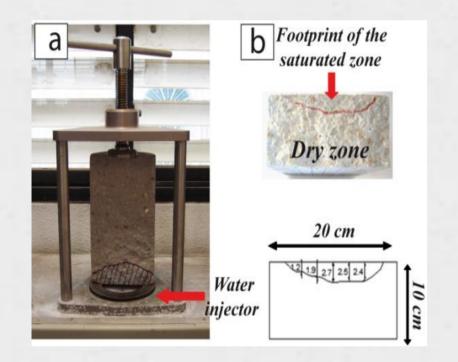
Ground-penetrating radar Nondestructive techniques

Infrared Thermography Water front penetration

Concrete Durability

GROUND-PENETRATING RADAR

This research describes the laboratory experiments carried out to analyze the effect on GPR signals of penetration of water under pressure in hardened concrete specimens of different W/C ratio.



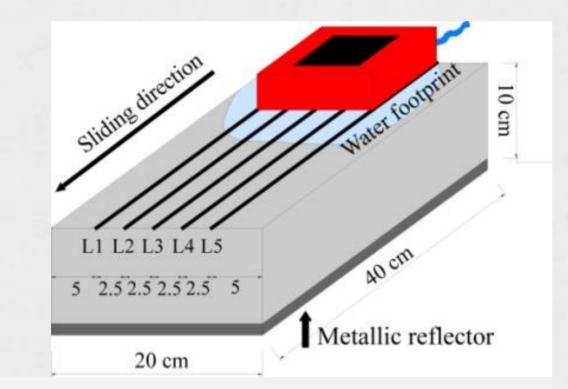
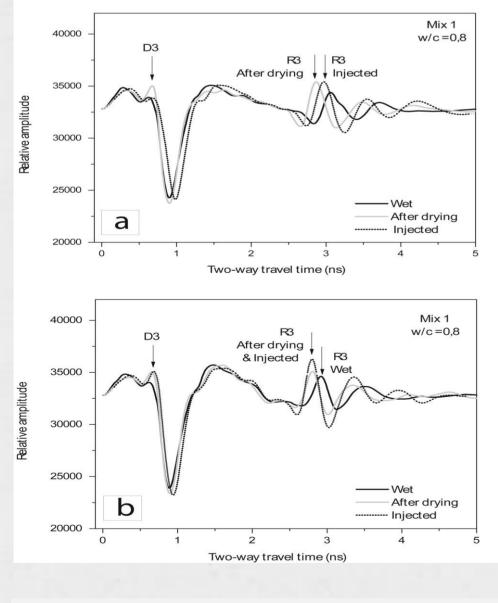


Figure 1. Water Figure injection equipment profond and footprint of a specimen

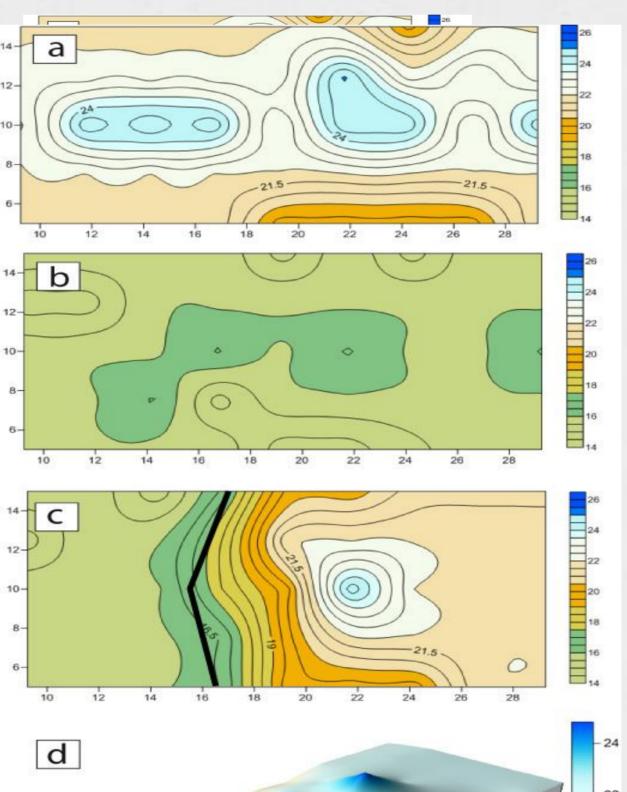
Figure 2. Positions of the profile lines. Profiles offset: 2,5 cm

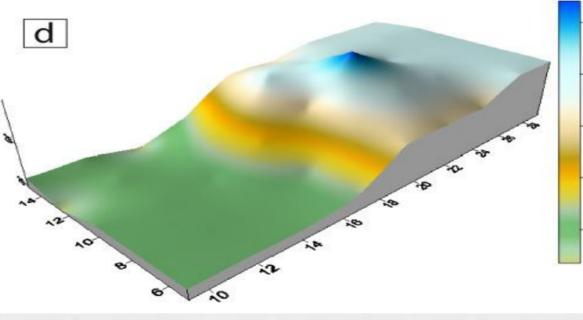


The survey was conducted by measuring the velocities (the real permittivity) and amplitudes of the waveforms level), (wave energy recorded when the concrete specimens were first saturated, then partially dried finally injected with and pressurized water.

Figure 3. Typical signals recorded in the 3 sessions in two different parts of concrete acquired with a 2,6 GHz antenna: (a) the injected and (b) the non-injected area

The results showed that all the wave parameters studied were influenced by the presence of water in the specimens and a similar pattern behavior was observed regardless the W/C ratio.





Wave energy level enabled to distinguish what area of the concrete specimens were affected by the water injection.

Wave **Figure** energy level contour when maps specimen was wet after drying (b) and process injected with water acquired with the 2,6 GHz antenna (c **d**). and (X, Coordinates units are cm.

INFRARED THERMOGRAPHY

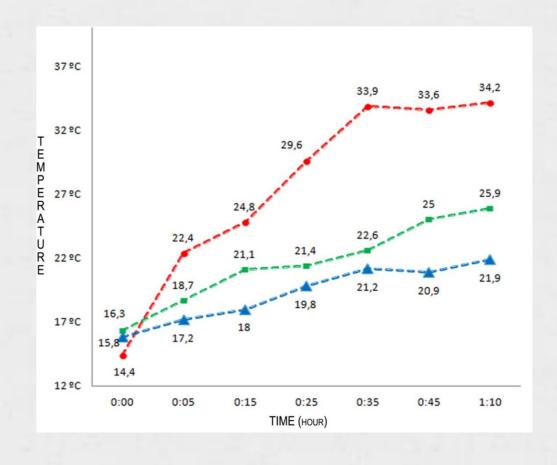


Figure 5. Graph showing temperature change in the 3 areas of concrete specimen. The red dashed line represents temp. increase in the central image, the green one the increase in the dry zone and the blue one the increase in the moisturized area



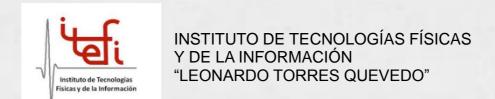


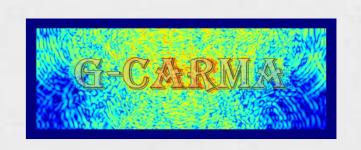








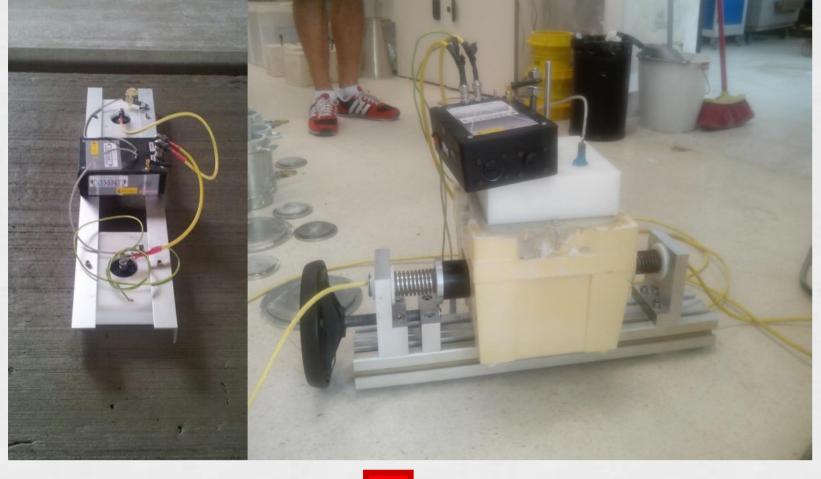




Monitoring of curing process in precast concrete by Wireless Sensors Network

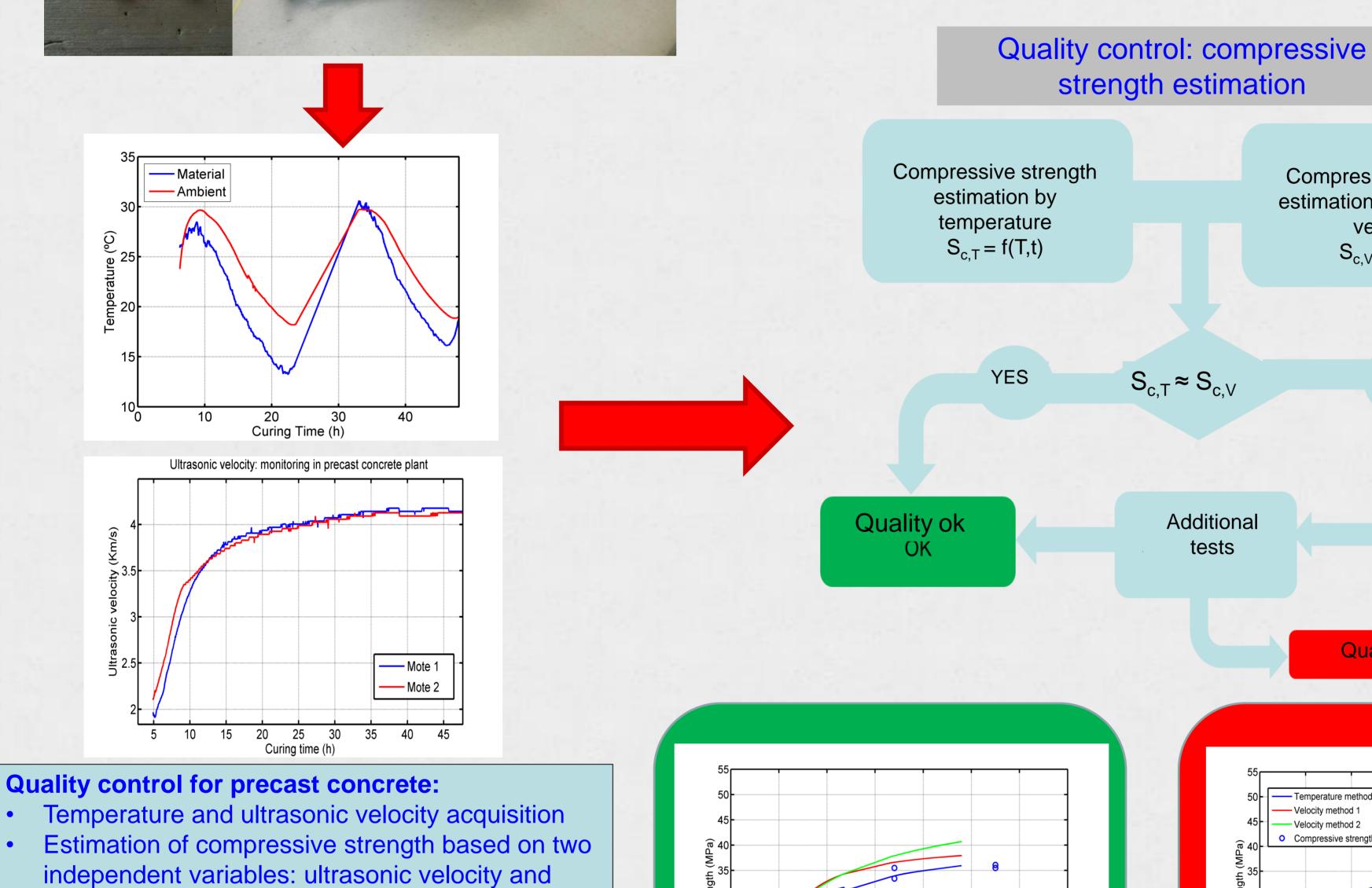
J. Ranz, S. Aparicio, D. Lluveras, J. Olivera, M. Molero, M.G. Hernández and J.J Anaya.

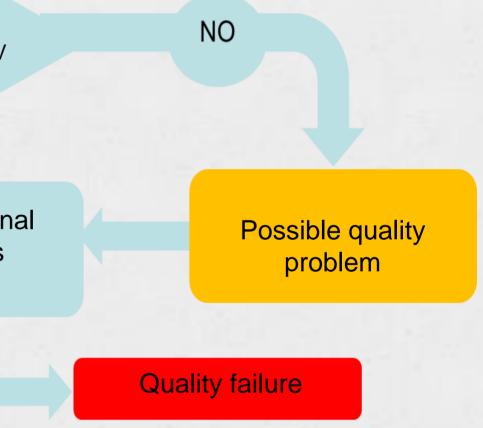
Currently, the use of precast concrete elements has gained importance because it offers many advantages over site-cast concrete. The compressive strength determines if the precast can be stripped from the form and manipulated. This parameter is measured using destructive testing over cylindrical or cubic samples resulting in a "pass or fail" evaluation. The system presented here is able to monitor temperature, relative humidity and ultrasonic signals of the precast concrete and estimate the compressive strength from these parameters, that is, by nondestructive testing. The monitoring is performed using wireless sensor networks.



WilTempUS system

- Wireless scalable system.
- Ultrasonic, Temperature and Relative Humidity sensors.
- Data acquisition software
- Bandwidth 250 KB/s.
- More than 10 devices has been simultaneously tested.
- One week monitoring with 3 AA rechargeable batteries (2.5 A-h) per device.





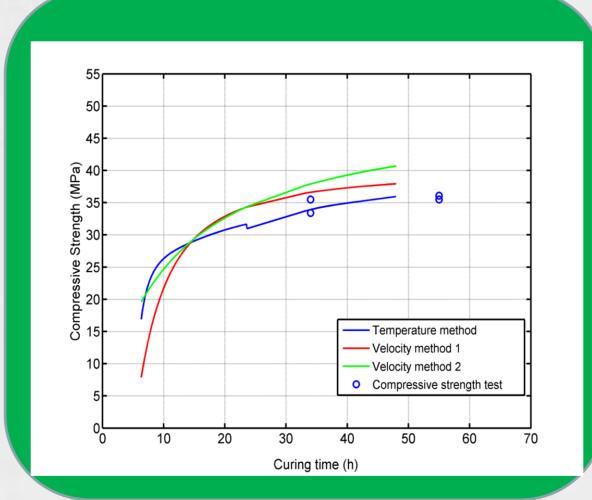
Compressive strength

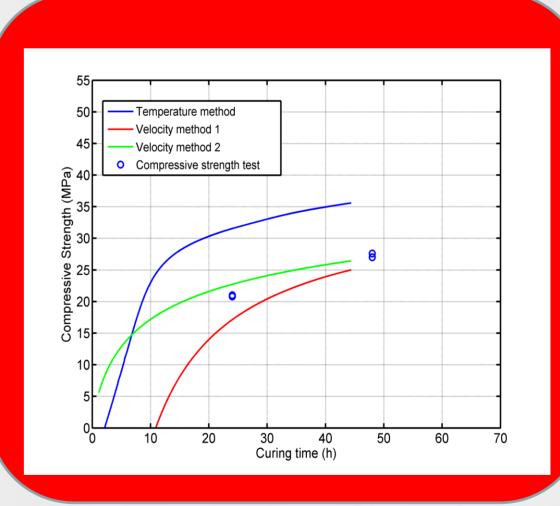
estimation by ultrasonic

velocity

 $S_{c,V} = f(T,t)$

- Estimation of compressive strength based on two independent variables: ultrasonic velocity and temperature.
- Detection of problems due to unexpected dosage changes.
- Tested on laboratory and precast concrete factories.
- Real time estimation will be implemented





Recent publications:

- J. Ranz, S. Aparicio, H. Romero, M. J. Casati, M. Molero, M. G. Hernández. Monitoring of freeze-thaw cycles in concrete using embedded sensors and ultrasonic imaging. Sensors 14 (2), 2014, 2280-2304.
- M. Molero, U. Iturrarán-Viveros, S. Aparicio and M.G. Hernández. Optimized OpenCL implementation of the Elastodynamic Finte Integration Technique for viscoelastic media. Computer Physics Communications, 185 (10), 2014, 2683-2696.
- E. Niederleithinger and J. Ranz. Quality assurance of diaphragm walls by sonar measurements model study. Proceedings of the ICE Geotechnical Engineering 167 (2); 2014, 217-226...
- J. Olivera, M. González, J.V. Fuente, R. Varga, A. Zhukov and J.J. Anaya. Embedded Stress Sensor based on amorphous ferromagnetic microwire for concrete SHM. Sensors 14, 2014, 19963-19978.
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- S. Aparicio, J.V. Fuente, J. Ranz, J. Aliques, M.A.G. Izquierdo and R. Fernández. The use of wireless sensor networks to monitor the setting and hardening processes of self-compacting concrete. Nondestructive Testing of Materials and Structures RILEM Bookseries Vol. 6, 2013, pp. 479-484. ISBN: 978-84-8363-704-3.
- S. Aparicio, J. Ranz, R. Fernández, V. Albert, J. V. Fuente, M. G. Hernández. Non-destructive monitoring of curing process in precast concrete. IOP Conf. Series: Materials Science and Engineering 42 (2012) 012050, 5 pgs.

Acknowledgements

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Department of Construction Engineering http://dec.upc.edu/

Research Group of Structural Technology



Research sub-group of Concrete Structures

Participants in TU1404: Jesús Bairán & Denise Ferreira

Self developed testing techniques & methods

- Concrete's Poisson modulus under multiaxial cyclic pressure
- Structural elements under cyclic multiaxial loading

Recent & ongoing research topics:

- Experimental research at material & structural levels
- Early age characterization of concrete
- Structural elements under cyclic multiaxial loading
- Structural effects of corrosion
- Rehabilitation and repair of D regions with initial damage
- Partially prestressed elements & Control of cracking

Development of nonlinear numerical models & software

- Structural evaluation since early ages
- Partial prestress & control of cracking
- Multiaxial force-interaction & shear failures
- Effects of corrosion in structural response
- Assessment of existing infrastructure
- Evaluate efficiency of repair/retrofit actions accounting for damage
- Mechanical simulation of corrosion damage and models for monotonic loading and fatigue.

Development of analytical formulations

- Compression-chord model for ultimate shear strength
- Control of cracking with partial prestress
- Nonlinear design of concrete frames

Ongoing research projects

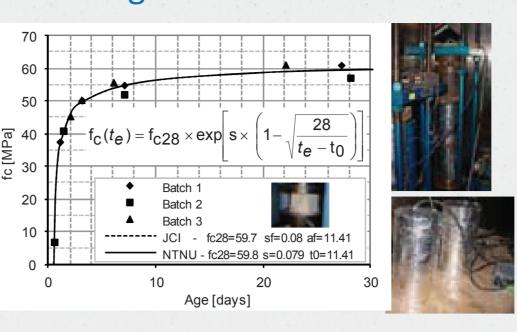
- Performance-based-design of partially prestressed concrete structures. Proposal of new design methodology, experimental verification and design criteria. Financed by Spanish Ministry of Economics Competitiveness & ERDF (BIA2012-36848), 2012-2015
- 4 PhDs completed in the last 5 years; 9 PhD projects running

Recent most relevant publications:

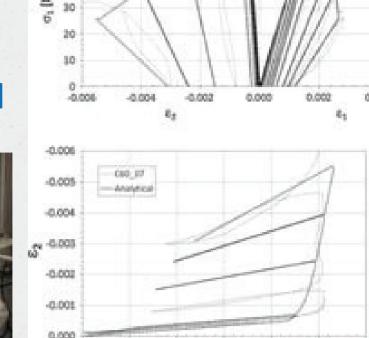
- Ferreira D., Crespo M.D., Marí A., Bairán J., Thermo-mechanical simulation of the ConCrack Benchmark RL1 test with a filament beam model, Eng Stru, 2014, vol. 73, p. 143-159.
- Ferreira D, Bairán J, Marí A, Efficient 1D model for blind assessment of existing bridges: simulation of a full scale loading test and comparison with higher order continuum models, SIE 2014.
- Marí A, Bairán B, Cladera A, Oller E, Ribas C. Shear-flexural strength mechanical model for the design and assessment of reinforced concrete beams. SIE, 2014.
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Open positions for Short Term Scientific Missions (STSM): Analysis and/or upgrading models & software developed in the group

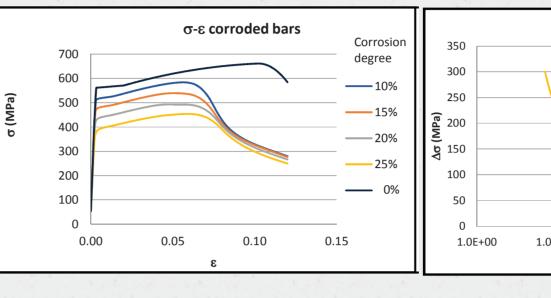
Early age experimental and modelling works on SCC

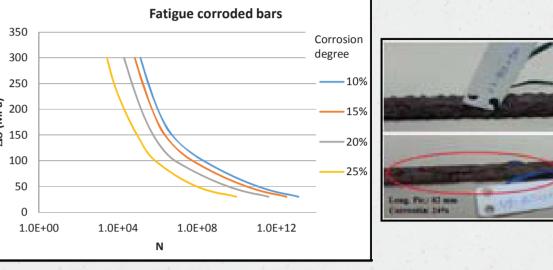


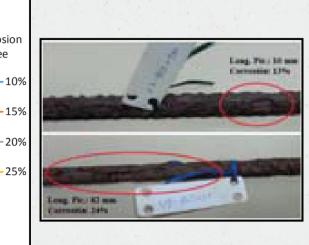
Poisson modulus under multiaxial cyclic load



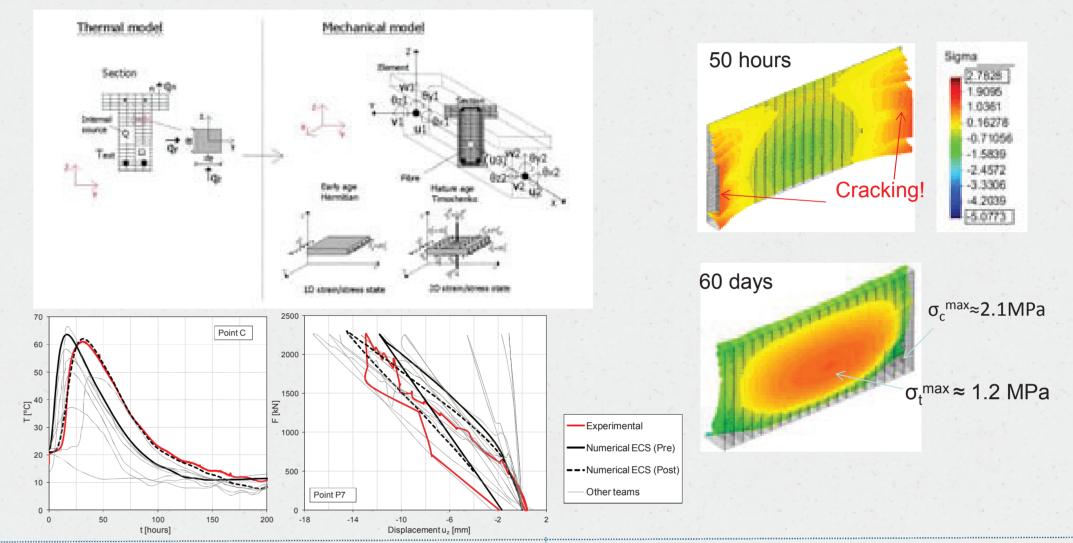
Corrosion of steel bars: experimental and modelling



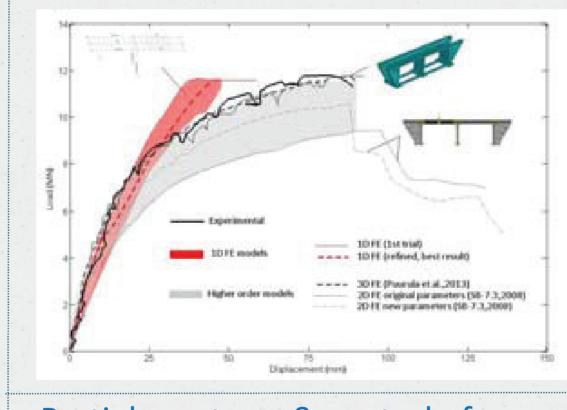


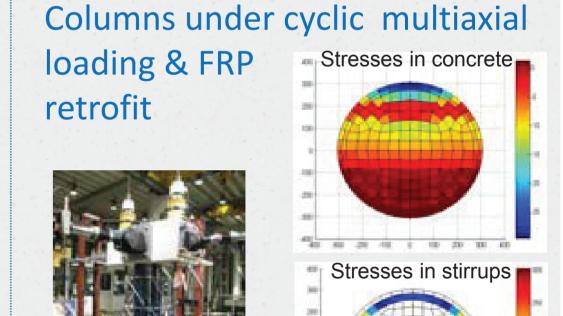


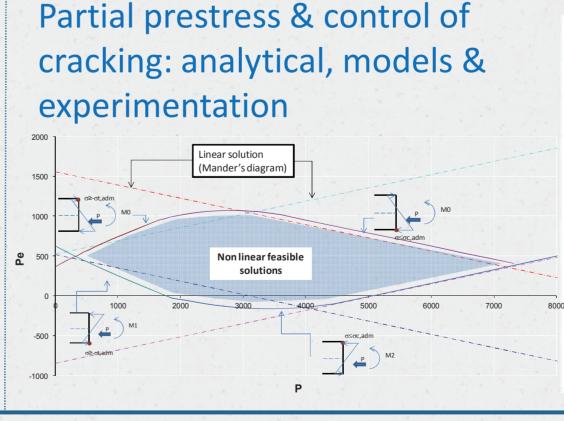
Participation in Concrack Benchmark (Ceos.fr) – RL1 test, 2010

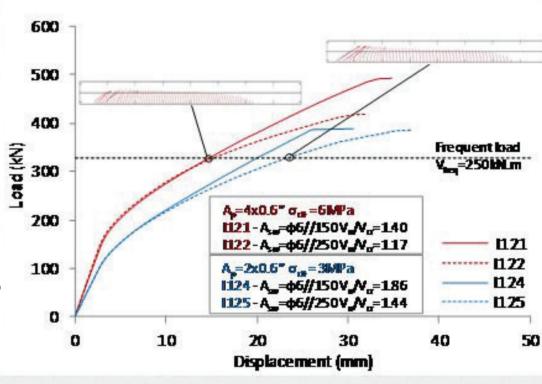


Assessment of existing infrastructure & retrofit









Research sub-group of Concrete Technology

Self developed testing techniques & methods

- Barcelona test to assess post-cracking behavior of FRC
- Inductive method to assess of fiber content and orientation in SFRC

Recent public funding research projects

- Management and safety in hydraulic infrastructures. Spanish Ministry of Economics Competitiveness (BIA2013-49106-C2-1-R), 2014-16.
- Ghost aggregate to obtain high-performance pervious concrete. Spanish Ministry of Economics Competitiveness (BIA2013-49106-C2-1-R), 2014-16.

Recent most relevant publications

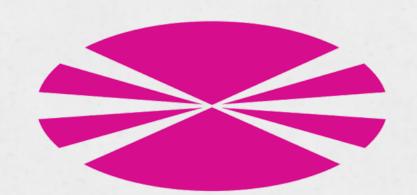
- Ikumi T., Cavalaro S.H.P., Segura I. Aguado A. Alternative methodology to consider damage and expansions in external sulfate attack modeling, Cement and Concrete Research, 2014, vol. 63, p. 105-116.
- Blanco A., Pujadas, P., Cavalaro S.H.P., de la Fuente A., Aguado A. Constitutive model for fibre reinforced concrete based on the Barcelona test, Cement and Concrete Composites, 2014, vol. 53, p. 327-340.
- Manso, S., De Muynck, W., Segura, I., Aguado, A, Steppe, K., Boon, N., De Belie, N. Bioreceptivity evaluation of cementitious materials designed to simulate biological growth, Science of the Total Environment, 2014, vol. 481, p. 232-241.











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Main research lines

Management of Construction & Demolition Waste

Recycled aggregates

Concrete with mixed recycled aggregate

Concrete with recycled concrete aggregates

Concretes with biomass ash

Concrete-steel bond

Concrete maturity

Non-destructive testing of concrete

Structural testing













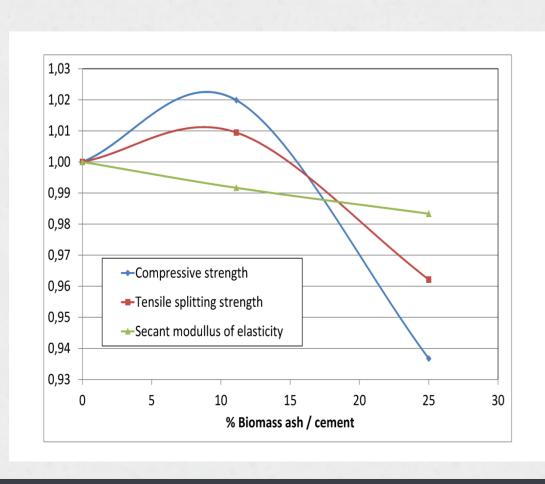
Most recent research projects

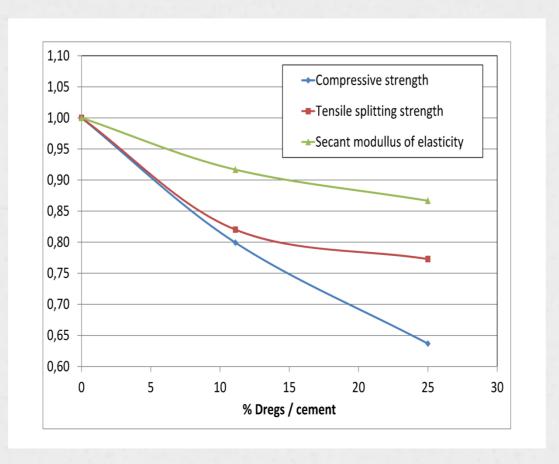
□ Project TECNOVAL. Development of technologies for the valuation of CDW in innovative applications. Funding Agency: CDTI – Ministerio de Economía (INNTERCONECTA Galicia). Companies: SACYR, Prefabricados Castelo, CIMARQ & Prefabricados Faro. 2012 - 2014.





□ Project PANTERA. Application of industrial waste coming from paper and tyres no longer in use for the construction of ecological lightened and other construction materials. Funding Agency: CDTI – Ministerio de Economía (INNTERCONECTA Galicia). Companies: SACYR, ENCE, Xilo Galicia & CYE. 2013 - 2014.





Most recent/important research publications

- □ Estimation of the annual production and composition of C&D Debris in Galicia (Spain). Waste Management. 2010.
- □ A new procedure to ensure structural safety based on the maturity method and limit state theory. Construction and Building Materials. 2012.
- ☐ Properties of Plain Concrete Made with Mixed Recycled Coarse Aggregate. Construction & Building Materials. 2012.
- □ Evaluation of strand bond properties along the transfer length of prestressed lightweight concrete members. Engineering Structures. 2013.
- ☐ Use of fine and coarse recycled concrete aggregate on structural self-compacting concrete coming from a precast production facility. Latin American Congress REHABEND 2014.
- ☐ Influence of recycled aggregates in the relationship between non-destructive testing and mechanical properties of concrete. Latin American Congress REHABEND 2014.
- Study of the use of biomass ashes for the production of a new construction material. Congress Greencities & sostenibilidad. 2014.
- □ A study of the strength evolution of mortars with fine recycled aggregate by ultrasound and an estimate of effective water/cement ratio. Congress Greencities & sostenibilidad.

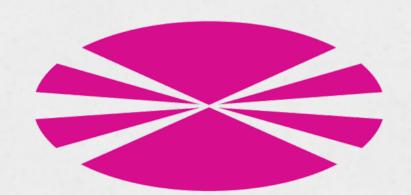
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Center for Technological Innovation in Construction and Civil Engineering



Main research lines

A new methodology and formulation for the estimation of the early compressive strength and E-modulus on conventional and recycled concrete by means of non-destructive tests.

Main research techniques

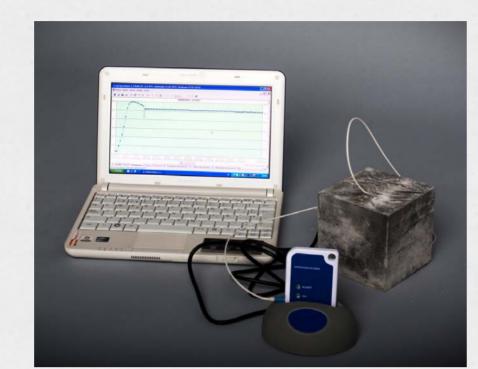
Monitoring of internal and external temperatures.

Curing of specimens at different temperatures.

Non-destructive testing:

- Ultrasonic
- Hammer rebound
- Cementometer

Structural testing.









Materials subject of research

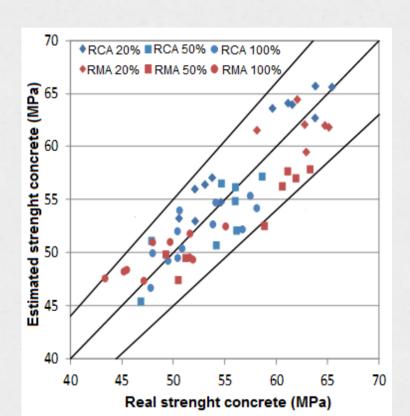
Conventional concrete and selfcompacting concrete.

Eco-concretes:

- With fine and coarse recycled concrete aggregates.
- With mixed recycled aggregates.
- With biomass ash

Eco-mortars with fine recycled concrete aggregates.

New material made with biomass ash.







Elements subject of study

Cubic and cylindrical test specimens.

On site construction:

- Bridge decks
- -Sidewalks

Precast elements:

- -Reinforced beams
- -Prestressed beams
- Walls and pre-slab

Most recent research projects

Project TECNOVAL. **Development of technologies** for the valuation of CDW in innovative applications.

Funding Agency: CDTI – Ministerio de Economía (INNTERCONECTA Galicia). Companies: SACYR,

Prefabricados Castelo, CIMARQ & Prefabricados Faro. 2012 -2014.



Most recent/important research publications

- Empirical definition of effective water/cement ratio in mortars with recycled aggregate depending on the absorption. International Congress on sustainable construction and ecoefficient solutions 2015. (Full paper accepted on March,19th,2015)
- ☐ Influence of recycled aggregates in the relationship mechanical non-destructive testing and between properties of concrete. Latin American Congress REHABEND 2014.
- ☐ Use of fine and coarse recycled concrete aggregate on structural self-compacting concrete coming from a precast production facility. Latin American Congress REHABEND 2014.
- A study of the strength evolution of mortars with fine recycled aggregate by ultrasound and an estimate of effective water/cement ratio. Congress Greencities & sostenibilidad. 2014
- Study of the use of biomass ashes for the production of a new construction material. Congress Greencities & sostenibilidad. 2014.

Address: E.T.S. Ingenieros de Caminos, Canales y Puertos. Campus de Elviña. 15071 A Coruña (Spain). Tel.: +34 881 01 6036. E-mail address: m.velay@udc.es

☐ Project PANTERA. Application of industrial waste coming from paper and tyres no longer in use for the construction of ecological lightened and other construction materials. Funding Agency: CDTI -Ministerio de Economía (INNTERCONECTA Galicia). Companies: SACYR, ENCE, Xilo Galicia & CYE. 2013 -2014.







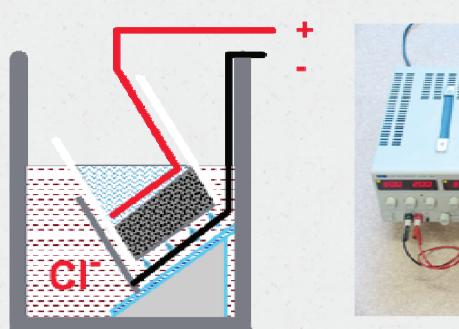


CHALMERS

Division of Building Technology

Rapid Chloride Migration (RCM) Test

A well-established rapid test method for evaluating the resistance of concrete to chloride ingress







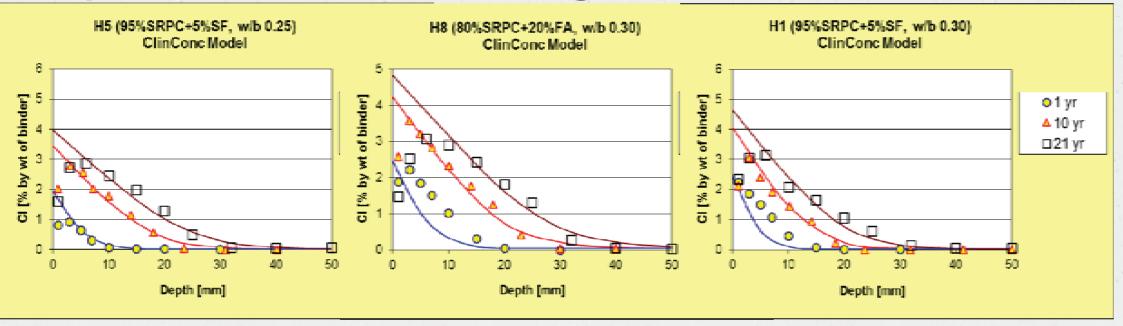
$$D = \frac{RTL}{zF\Delta E} \cdot \frac{x_{d} - \alpha \sqrt{x_{d}}}{t} \quad \alpha = 2\sqrt{\frac{RTL}{zFU}} \cdot \text{erf}^{-1}\left(1 - \frac{2c_{d}}{c_{0}}\right)$$

Rapid Corrosion Test (RapiCor)

A rapid and reliable test method for nondestructive evaluation of corrosion conditions of reinforced concrete structures



ClinConc – A mechanistic model for prediction of chloride ingress in concrete





SBUF Project 12684 Report

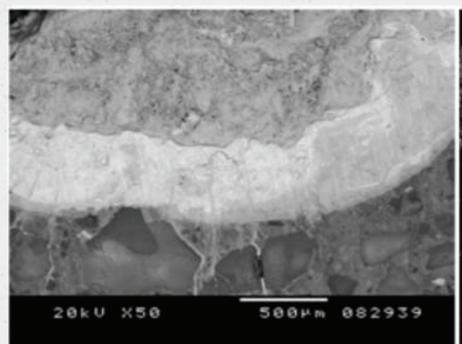
Chloride Ingress in Concrete Exposed to Marine Environment

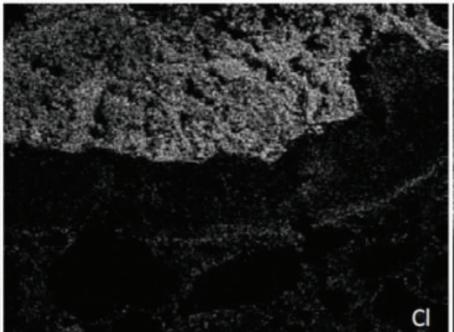
-Field data up to 20 years' exposure

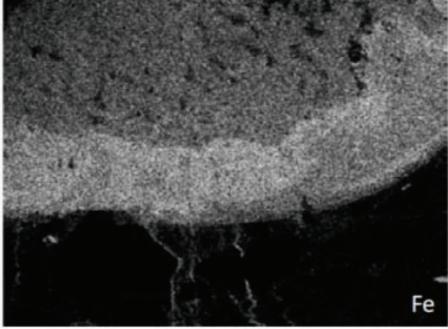
Dimitrios Boubitsas, Tang Luping and Peter Utgenannt

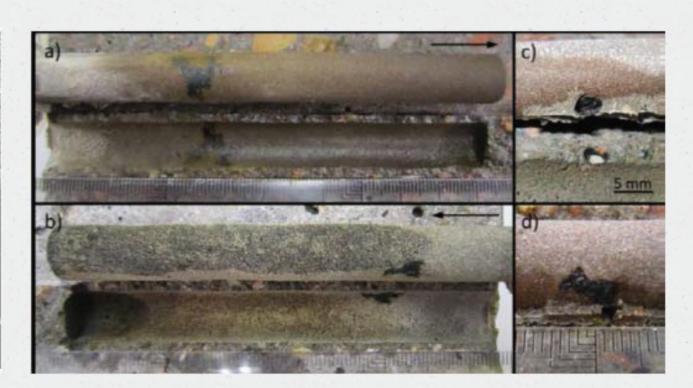
Chloride Induced Corrosion of Reinforcement Steel in Concrete

Threshold Values and Ion Distributions at the Concrete-Steel Interface









Pablications related to the Action

- ➤ Tang L., "Engineering expression of the ClinConc model for prediction of free and total chloride ingress in submerged marine concrete", Cement and Concrete Research, 38(8-9) (2008) 1092-1097.
- ➤ Tang L. and Utgenannt P., "A field study of critical chloride content in reinforced concrete with blended binder", Materials and Corrosion, 60(8) (2009) 617-622.
- ➤ Silva N., Tang L., Lindqvist J.E. and Boubitsas D., "Chloride profiles along the concrete-steel interface", *International Journal of Structural Engineering*, **4**(1/2) (2013) 100-112.
- ➤ Tang L. and Lindvall A. "Validation of models for prediction of chloride ingress in concrete exposed in de-icing salt road environment", *International Journal of Structural Engineering*, **4**(1/2) (2013) 86-99.
- ➤ Boubitsas D. and Tang L., "The influence of reinforcement steel surface condition on initiation of chloride induced corrosion", *Materials and Structures*, DOI 10.1617/s11527-014-0343-2, published online 11 June 2014.
- ➤ Babaahmadi A., Tang L., Abbas Z., Zack T. and Mårtensson P., "Development of an electro-chemical accelerated ageing method for leaching of calcium from cementitious materials", *Materials and Structures*, DOI 10.1617/s11527-015-0531-8, published online 15 January 2015.









Numerical Modeling of Internal Curing in High-Performance Concrete



Materials Science & Technology

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²Department of Building Physics and Building Materials, Lodz University of Technology, Poland

³Institute for Building Materials, ETH Zürich, Switzerland

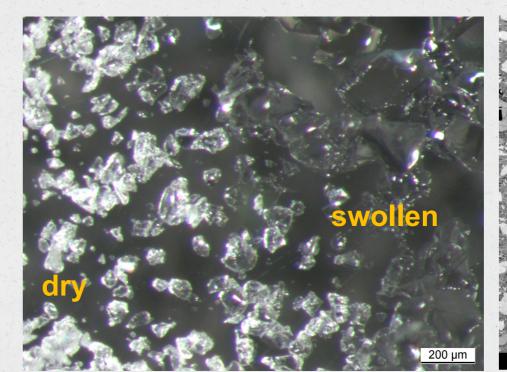
⁴Department of Civil, Environmental and Architectural Engineering, University of Padua, Italy

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Introduction

Internal curing by means of superabsorbent polymers (SAP) [1] has been recently applied as an efficient method for counteracting self-desiccation and self-desiccation shrinkage. The SAP uniformly distributed in the concrete, Fig. 1, act as internal water reservoirs, which first absorb water during mixing and further release it to the surrounding cement paste during maturing.

Poromechanical modeling can be very useful in understanding the fundamental processes related to water transport from SAP to the surrounding cement paste [2]. Further, it allows predicting the overall, macroscopic behavior of concrete with internal curing [3].



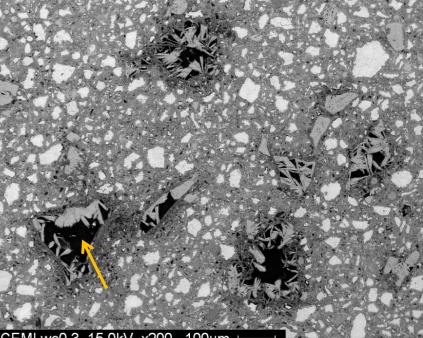


Figure 1: Solution polymerized SAP in a dry and swollen state (left, optical microscopy) and SAP-entrained voids in hardened cement paste (right, BSE microscopy).

Meso-level simulations

Application of poromechanical model [4] allows studying the **kinetic availability of water** by analyzing water migration at the meso-level, that is, at the scale level of single SAP reservoirs, Fig. 2.

$$\begin{array}{ll} \textbf{Accumulation} & n \Big(\rho^w - \rho^{gw} \Big) \frac{\partial S_w}{\partial p^c} \frac{\partial p^c}{\partial t} + \\ & - div \Bigg[\rho^g \frac{M_a M_w}{M_g^2} \mathbf{D}_d^{gw} grad \bigg(\frac{p^{gw}}{p^g} \bigg) \Bigg] + div \Bigg[\rho^{gw} \frac{k \mathbf{I} k^{rg}}{\mu^g} \Big(- grad p^g \Big) \Bigg] + \\ & + div \Bigg[\rho^w \frac{k \mathbf{I} k^{rw}}{\mu^w} \Big(- grad p^g + grad p^c \Big) \Bigg] = \\ & \mathbf{Sources/sinks} & = \frac{\rho^{gw}}{\rho^s} \big(1 - S_w \big) \dot{m}_{hydr} + \frac{\rho^w}{\rho^s} S_w \dot{m}_{hydr} - \dot{m}_{hydr} & \textbf{Highest transport efficiency during internal curing} \\ \end{array}$$

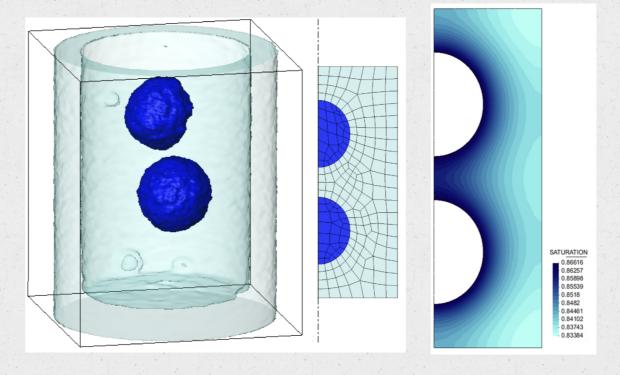


Figure 2: FEM mesh (middle) used in the simulations of the experimental setup [5] (left) and distribution of saturation degree at time instant of maximum saturation gradient, 150 h (right) (see [2]).

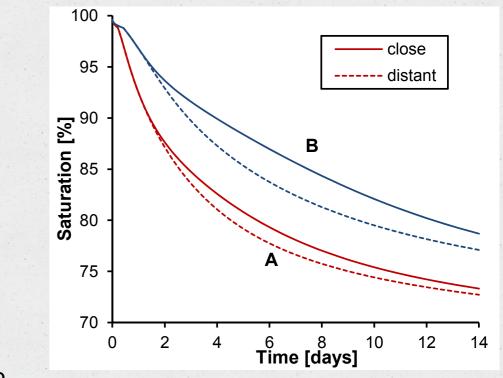


Figure 3: Meso-level results of the evolution of saturation degree in two points: in the direct vicinity of the reservoir (close) and in the maximum distance from it (for details see [2]).

At early stages of hydration water transport in the cured paste is an almost *instantaneous process*. For the sizes of SAP used commonly (couple hundreds µm) the whole volume of cured material is practically *uniformly* provided with curing water, Fig. 3.

Macro-level simulations

Based on the meso-level results, showing the uniform availability of curing water when the SAP are used, presence of internal curing can be described at the macroscopic level, Fig. 4, where the analyzed material is treated as homogenous, with **volume-averaged source term** (added to water mass balance equation).

Source term based on sorption isotherm of SAP (capillary suction)

$$\dot{m}_{IC}(p^c) = \frac{\eta}{1-\eta} \rho^w \frac{\partial S_w^{IC}}{\partial p^c} \frac{\partial p^c}{\partial t},$$

Source term based on chemical shrinkage (demand-supply)

$$\left(1 - \frac{\rho^{w}}{\rho^{s}}\right) m_{hydr\infty} \left(\alpha - \alpha_{0}\right) \leq \frac{\eta}{1 - \eta} \rho^{w}$$

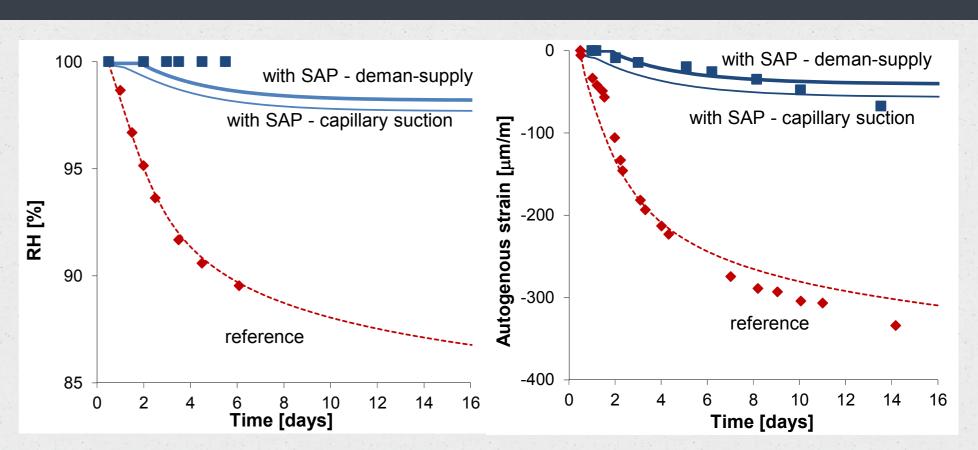


Figure 4: Comparison of the experimental (points) and simulation (lines) results obtained from macro-level simulations for the two source terms describing internal curing. Analyzed mortar samples of w/c 0.30 (reference) and w/c 0.30+0.04 (with SAP) (see [3]).

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- [1] Jensen OM, Hansen PF. Cem Concr Res 31(4) 2001: 647-54.
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- [3] Wyrzykowski M, Lura P, Pesavento F, Gawin D. Cem Concr Res 41(12) 2011:1349-1356
- [4] Gawin D, Pesavento F, Schrefler BA. Int J Numer Methods Eng 67(3) 2006: 299-331.
- [5] Trtik P, Münch B, Weiss JW, Herth G, Kaestner A, Lehmann, E, Lura P. *Int. Conf. on Material Science and 64th RILEM Annual Week*, September 6-10, 2010, Aachen, Germany









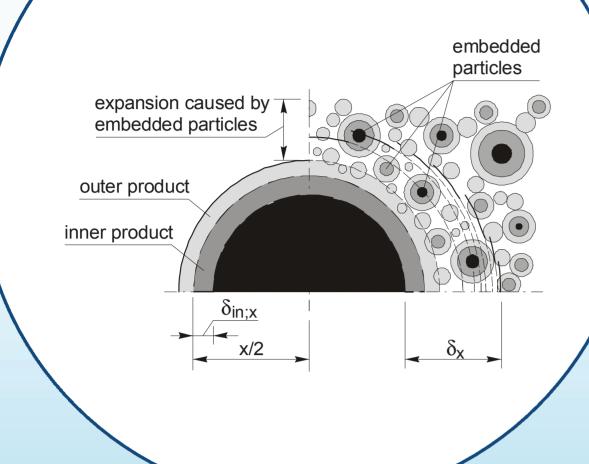
Multi-scale Modelling of Concrete

TUDelft

HYMOSTRUC 3D



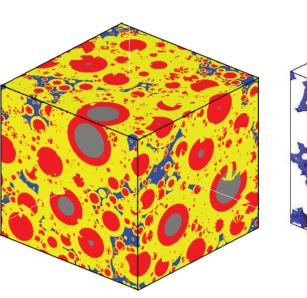
HYMOSTRUC

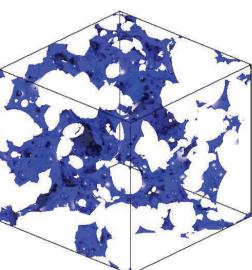


The basic HYMOSTRUC model [1,2] was developed for simulation of the reaction process and of the formation of the microstructure in hydrating Portland cement. In this model the degree of hydration is simulated as a function of the particle size distribution and of the chemical composition (C3S and C2S content) of the cement, the water/cement ratio and the reaction temperature.

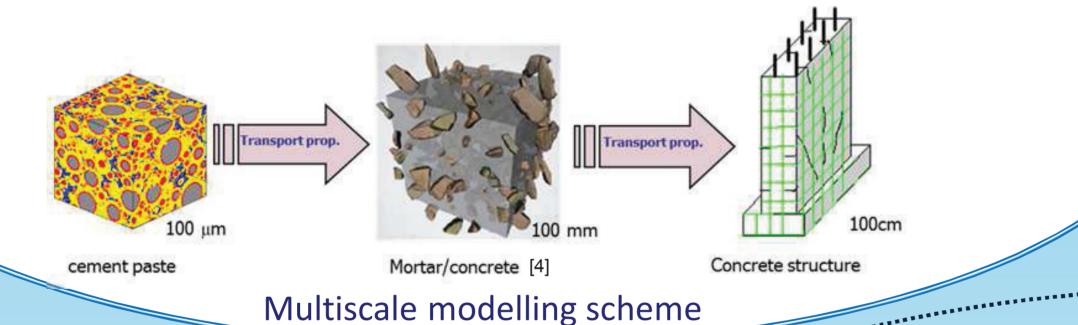
The HYMOSTRUC3D [3] was developed with the aim to generate a reliable microstructure of cement paste. The connectivity of capillary porosity, the percolation threshold of solid and pore phase were derived from the simulated microstructure. The HYMOSTRUC3D was further extended to simulate the hydration and microstructural development of binary and ternary cementitious system.

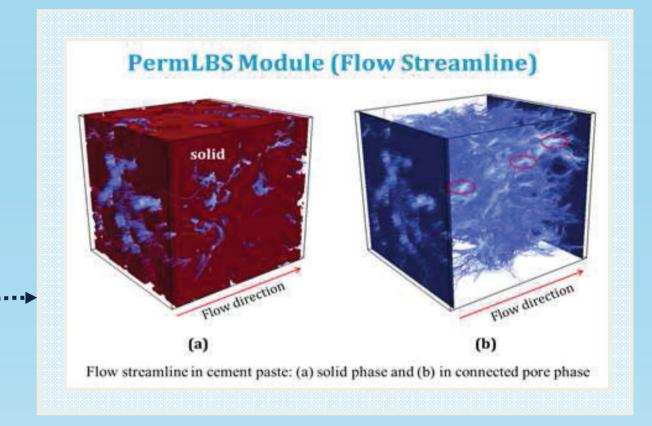
HYMOSTRUC3D



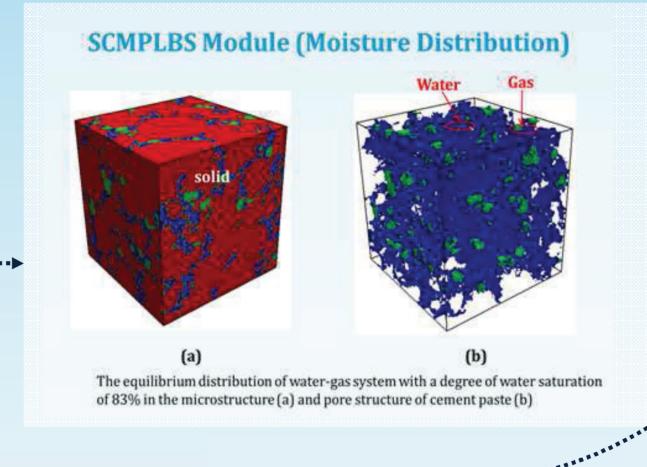


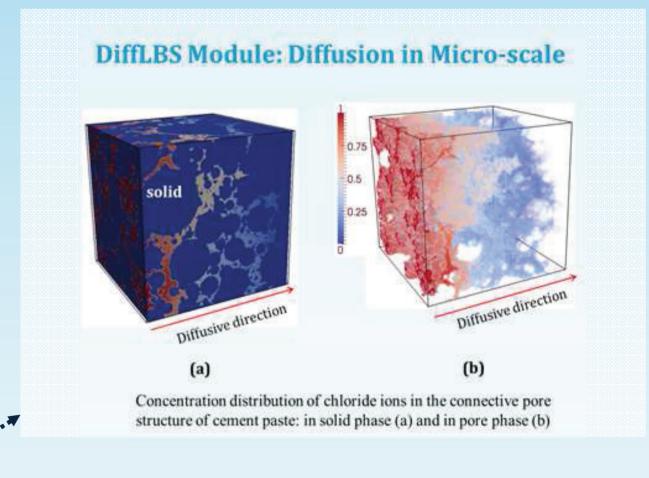
Multiscale Modelling of Transport Properties





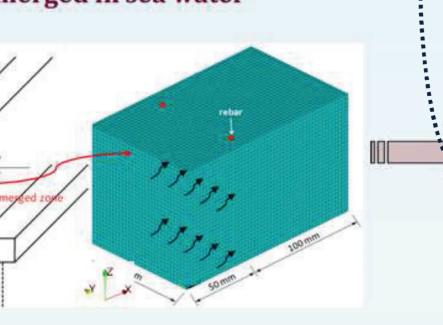
HYMOSTRUC3D - Lattice Boltzmann Method [5] Permeability of cement-PermLBS module Multiple-relaxation-time based materials at micro lattice Boltzmann model **SCMPLBS** module Micro-Moisture distribution in scale Multi-phase lattice ement-based materials ***** solver Boltzmann model at micro level DiffLBS module Ionic/gas diffusivity in cement-based materials Lattice Boltzmann model at micro level for diffusion





Application

Service life prediction of concrete bridge pier submerged in sea water

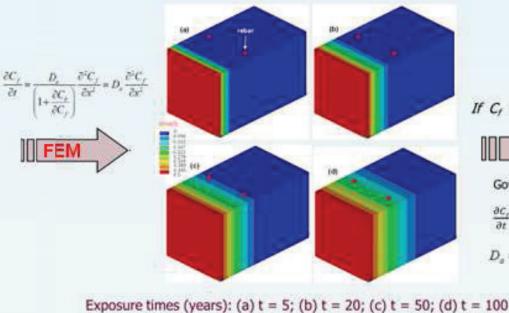


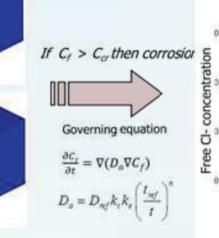
250×250×250 voxels with a resolution of 0.4 mm/voxel voxels with a resolution of 1 pm/voxel voxels with a resolution of 1 pm/voxel

D_{ext} = f(w/c, t, C_b, S_a, C_f) D_{ext} Upscalling (REV approach) D_c

Link different scales - Upscaling

Chloride concentration distribution





Service life of concrete bridge pier predicted by multiscale modelling The service life is



Reference

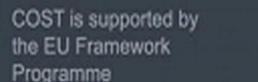
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Further information

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HYMOSTRUC3D light version free download
http://www.me.tudelft.nl











ConSensor BV

innovative sensors for concrete

www.ConSensor.nl

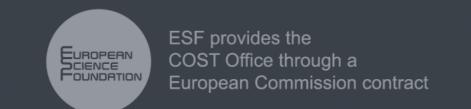


- ConSensor BV (Rotterdam, NL) is an SME, specialized in innovative sensors for concrete.
- Main product is the ConSensor 2.0 strength sensor based on conductivity measurement. It is remotely operated, all data are shown on the website www.consensor.eu
- In this COST action is to promote and evaluate the use of the conductivity method for concrete strength measurement, and to work on a standard for conductivity based strength sensors for concrete.
- ConSensor is interested in cooperation with universities and other SME's to develop sensors systems for concrete.

Contact: Wim Stenfert Kroese

mobile: +31 6 22 77 66 58 | e-mail: wsk@consensor.nl











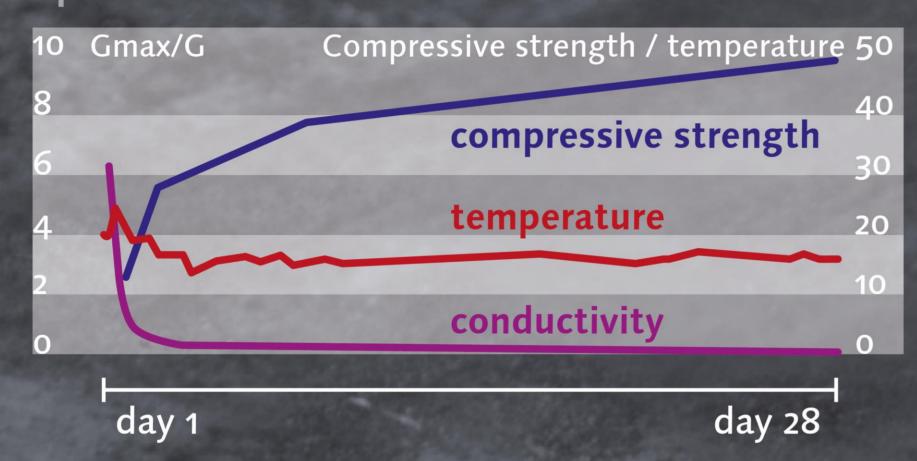
ConSensor 2.0

Conductivity strength sensor

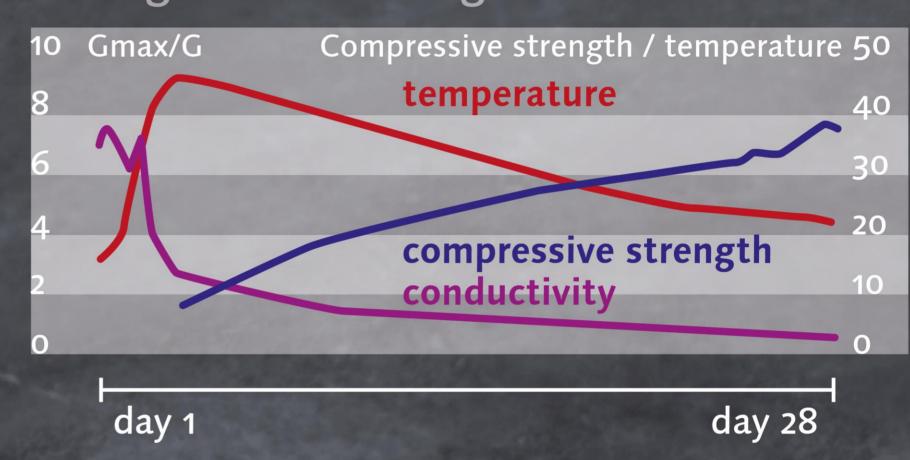
www.ConSensor.nl

Electrical conductivity is an excellent indicator of the strength development of curing concrete (1-28 days).

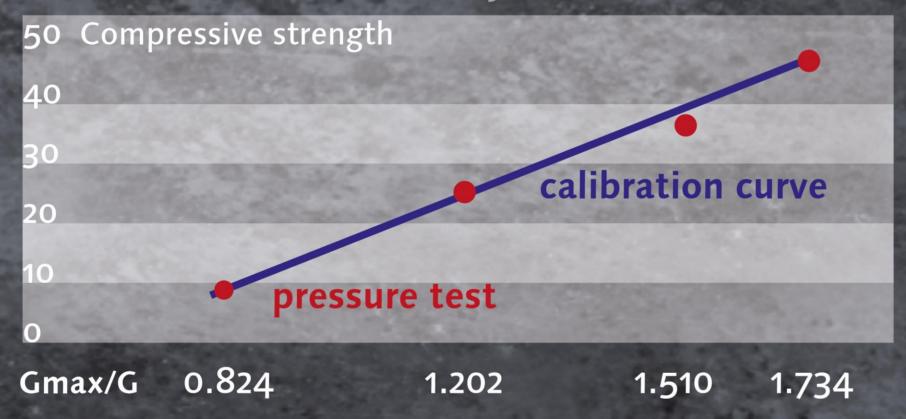
Measurements in test specimen of concrete mix



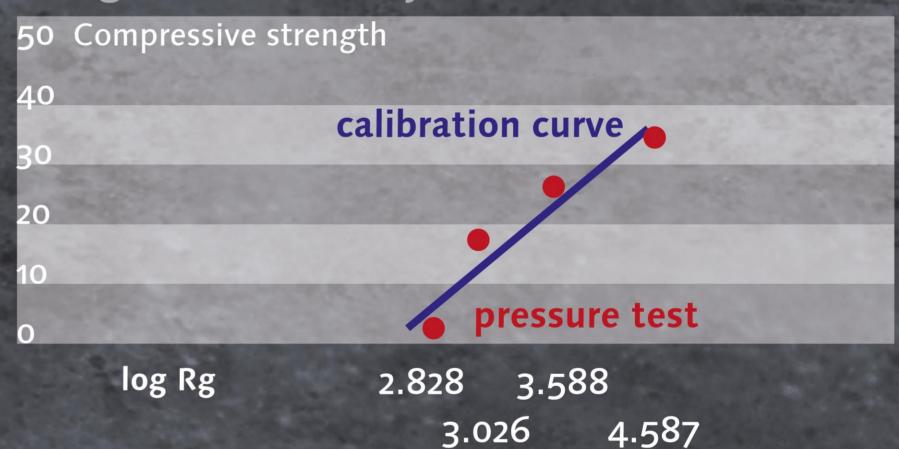
Measurements and concrete strength on building site



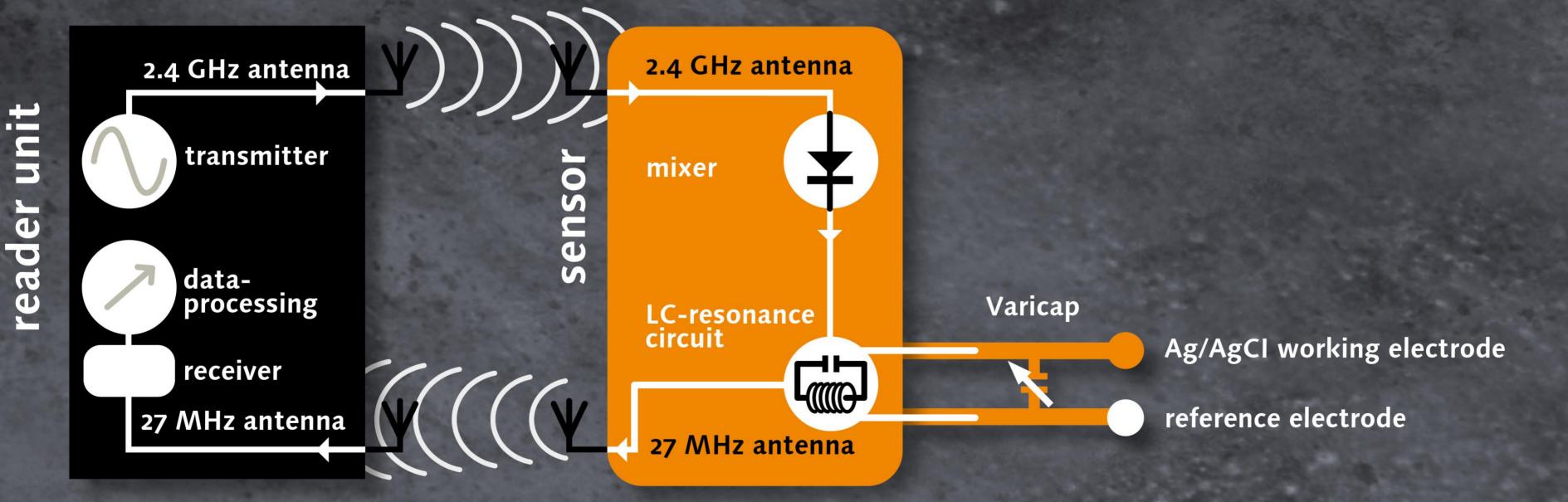
Concrete mix calibration based on conductivity



Calibration based on weighted maturity



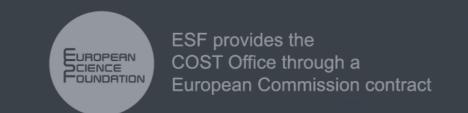
Contactless chloride sensor (new)



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CURING CONDITIONS ON CHLORIDE DIFFUSION COEFFICIENT

Utkan Çorbacıoğlu, Egemen Kesler, Yılmaz Akkaya

Istanbul Technical University

Motivation:

Concrete permeability and transport of chlorides are major factors which affect the service life of RC structures. However, many internal and environmental parameters affect the rate of chloride diffusion.

Objective:

Effects of concrete maturity, ambient temperature and testing methods on chloride diffusion coefficient are evaluated.

Chloride Diffusion Coefficient

Microstructure

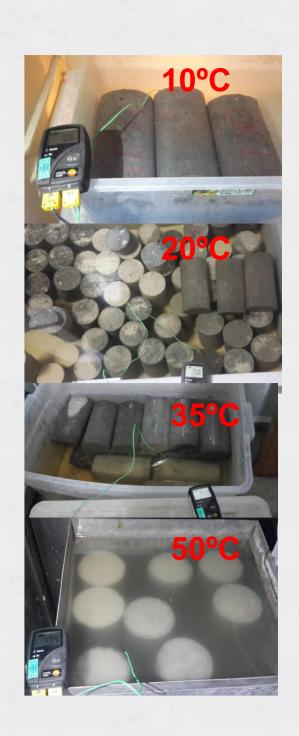
- -Materials
- -Mixture design
- -Hydration -Maturity
- -Chloride binding
- **Exposure conditions**
- -Temperature -Moisture
- -Chloride concentration
- **Test Methods** -Ponding
- -Migration
- -Electrical resistivity





D_{eM} 10⁻¹² m²/s

Test Methods



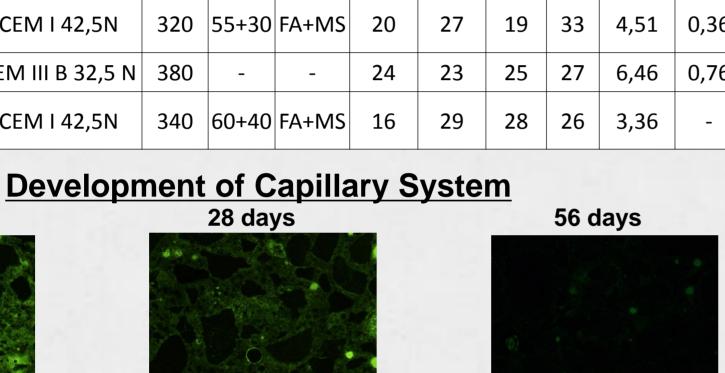
◆ 10ºC

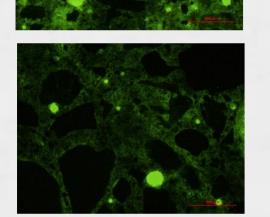
■ 20ºC

Mixture Designs

Mix No	Туре	W/C	CEM kg/m³			Additive kg/m³		CSand %	CA I %	CA II %	SP kg/m³	AEA kg/m³
CM-1	C30	0,40	CEM I 42,5N	296	80	FA	23	23	26	28	3,10	0,40
CM-2	C40	0,43	CEM II A	305	92	FA	25	26	23	26	3,42	-
CM-3	C45	0,38	CEM III B 32,5 N	380	-	-	23	25	26	26	4,75	-
CM-4	C50	0,36	CEM I 42,5 R	135	265	GGBFS	27	20	23	30	5,60	-
CM-5	C35 Fiber	0,38	CEM I 42,5N	320	55+30	FA+MS	20	27	19	33	4,51	0,36
CM-6	C45	0,38	CEM III B 32,5 N	380	-	-	24	23	25	27	6,46	0,76
CM-7	C40- Precst	0,36	CEM I 42,5N	340	60+40	FA+MS	16	29	28	26	3,36	-

			·			<u></u>						
Mix No	Туре	W/C	CEM kg/m³			Additive kg/m³		CSand %	CA I %	CA II %	SP kg/m³	AEA kg/m³
CM-1	C30	0,40	CEM I 42,5N	296	80	FA	23	23	26	28	3,10	0,40
CM-2	C40	0,43	CEM II A	305	92	FA	25	26	23	26	3,42	-
CM-3	C45	0,38	CEM III B 32,5 N	380	-	_	23	25	26	26	4,75	-
CM-4	C50	0,36	CEM I 42,5 R	135	265	GGBFS	27	20	23	30	5,60	-
CM-5	C35 Fiber	0,38	CEM I 42,5N	320	55+30	FA+MS	20	27	19	33	4,51	0,36
CM-6	C45	0,38	CEM III B 32,5 N	380	-	-	24	23	25	27	6,46	0,76
CM-7	C40- Precst	0,36	CEM I 42,5N	340	60+40	FA+MS	16	29	28	26	3,36	-



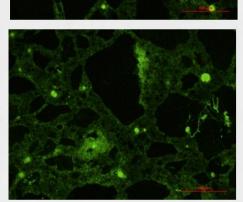


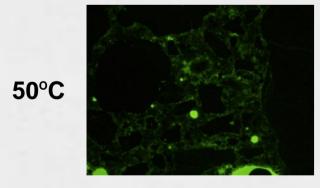
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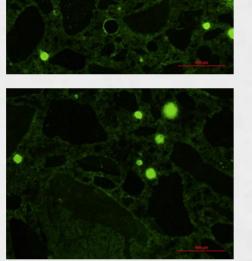
10°C

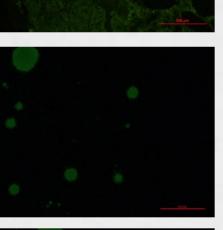
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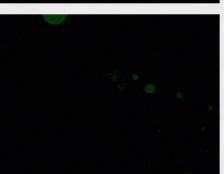
35°C

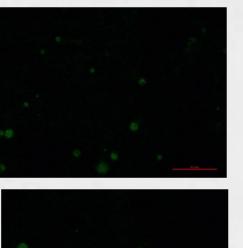










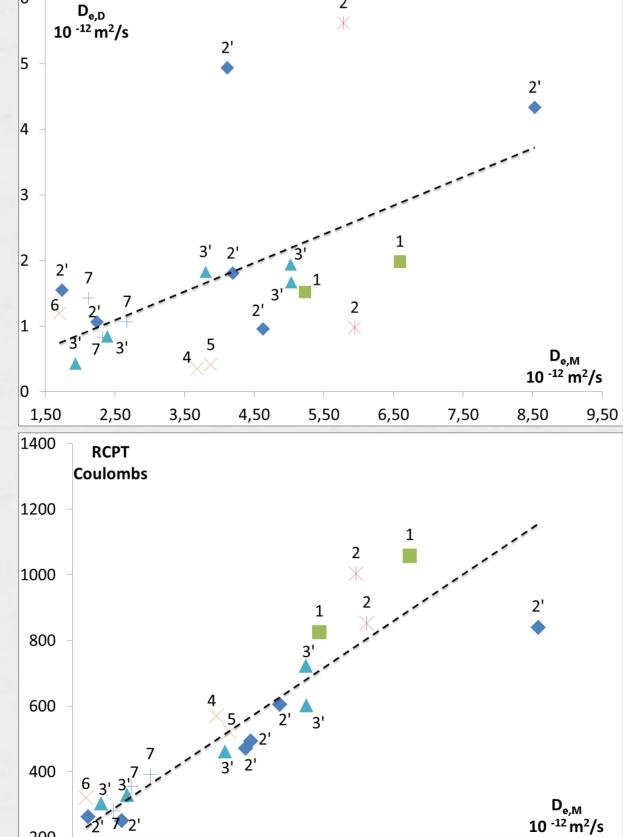




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FIELD STUDY

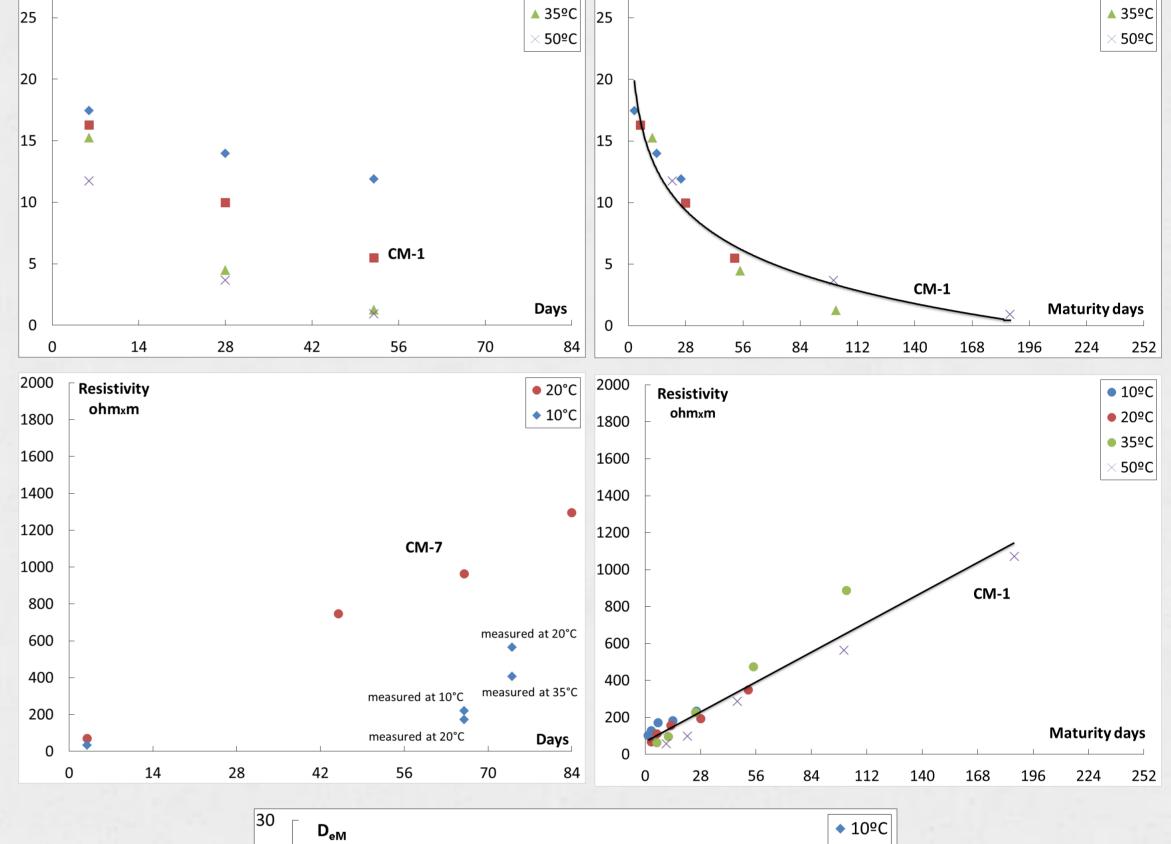
1 lab	380N+60+10/0,32	6,59	1,98	1058
1100	380B+60+10/0,32	5,23	1,52	826
2 lab	285+50+12/0,38	5,94	0,98	853
2100	285+50+12/0,38	5,78	5,62	1003
	285+50+12/0,38	4,63	0,96	605
	285+50+12/0,38	4,12	4,94	471
2' core	285+50+12/0,38	8,53	4,33	840
	285+50+12/0,38	4,20	1,80	493
	285+50+12/0,38	2,24	1,06	251
	285+50+12/0,38	1,74	1,54	263
	360+60+10/0,35	3,80	1,83	463
	360+60+10/0,35	2,32	0,83	330
3' core	360+60+10/0,35	1,93	0,43	304
	360+60+10/0,35	5,03	1,67	603
	360+60+10/0,35	5,02	1,94	724
4 lab	340+60+16/0,36	3,68	0,35	570
5 plant	340+60+20/0,36	3,88	0,41	522
6 plant	320+60+20/0,36	1,70	1,20	322
	320+60+20/0,38	2,67	1,07	391
7 plant	320+60+20/0,38	2,39	0,84	356
	320+60+20/0,38	2,12	1,43	281

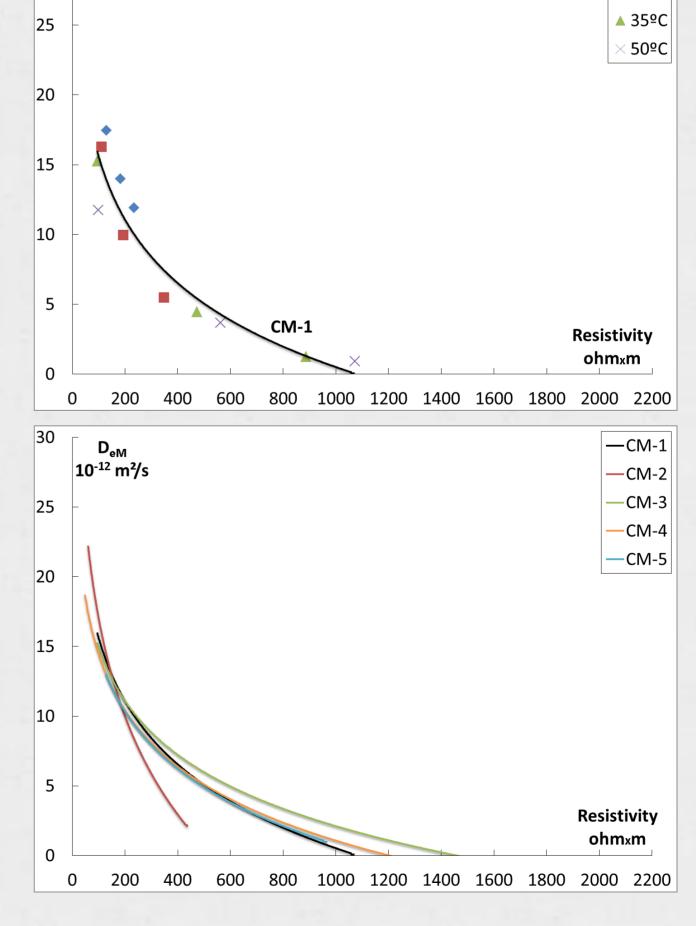


Diffusion Coefficient vs. Resistivity

■ 20ºC

D_{eM} 10⁻¹² m²/s





- Chloride diffusion of concretes with mineral admixtures are greatly affected by ambient temperature
- Maturity and microstructural development of concrete plays an important role in chloride diffusion
- Correlation between several test methods should be developed for field and laboratory measurements and corrosion activity.



5,50

6,50

7,50

8,50

9,50

4,50

3,50



10⁻¹² m²/s



■ 20°C



RELATIONSHIP BETWEEN MECHANICAL PROPERTIES OF **SFRC**

Merve AÇIKGENÇ

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INTRODUCTION

Steel fiber reinforced concrete (SFRC) has many superior mechanical properties compared with the conventional concrete especially in terms of tensile strength. Many studies in the literature have been conducted with experimental and analytical methods for evaluating these mechanical properties of SFRC, with the consideration of concrete mixture proportions, concrete types, age of curing, steel fiber type, geometry, aspect ratio and volume fraction, etc. As a result of these studies, it is well-known that steel fibers can remarkably enhance tensile strength of SFRC while barely can affect compressive strength. Thus tensile strength of SFRC is very important mechanical property. In the literature, splitting tensile strength test or flexural strength test is generally performed to determine tensile behaviour of SFRC. It is known that there are relations between mechanical properties of concrete. Relationships between mechanical properties have been investigated for mostly conventional concrete and fiber reinforced concrete. In this study, mechanical properties of SFRC were experimentally determined, and then the relations between compressive strength and splitting tensile strength, and between compressive strength and flexural strength were investigated for different V_f values. Eventually, highly correlated empirical relations proposed for the relation between flexural strength and splitting tensile strength. At the end of the study, an additional relation between flexural and splitting tensile strengths was revealed including V_f values. It is considered as a beneficial result for the preliminary design and analysis of SFRC.

EXPERIMENTAL PROGRAM

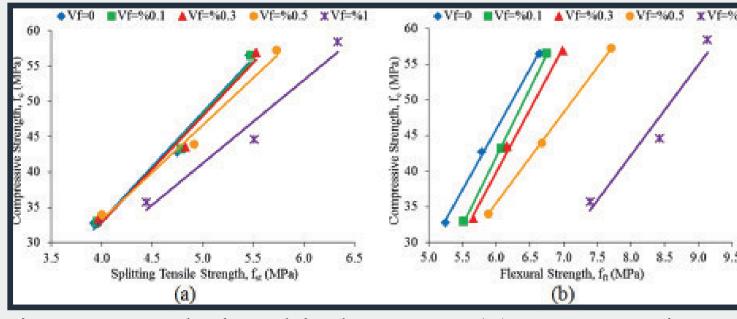
The mixtures were also produced with 0% (Reference), 0.1%, 0.3%, 0.5% and 1% volume fractions of steel fibers (V_f) . Then, mechanical properties were investigated for all mixtures. Hooked-end steel fibers were used to produce the SFRC mixtures. The fiber length (l) was 30 mm and the fiber diameter (d) was 0.75 mm. To investigate mechanical properties, compressive and splitting tensile strength tests were evaluated. In addition, 4-point flexural strength test was performed. Table 1. Mixture Proportions

Mix	PC	111/0	Aggregate	SP
Code	(kg/m^3)	w/c	(kg/m^3)	(%)
M1	500	0.40	1644	0.75
M2	400	0.50	1728	0.75
<u>M3</u>	300	0.60	1865	1.00

RESULTS AND DISCUSSIONS

Relationship of Mechanical Properties of SFRC

Figure 1a provides graphics of compressive strength (f_c) to splitting tensile strength (f_{st}) of concrete specimens. Correlation between compressive strength (f_c) and flexural strength (f_{ft}) of concrete specimens were also analysed by linear regression analysis, which is shown in Figure 1b. Linear regression analysis was carried out on these two groups of experimental data points. Through regression analysis, obtained empirical relations are demonstrated in Table 2. There are strong correlations above 95% for proposed relations in this study.



compressive and flexural strengths.

Table 2. Equations for the Relationship between Compressive-Splitting Tensile and Compressive-Flexural Strength

	-			
$V_f(\%)$	Equations for f_c - f_{st}		Equations for f_c - f_{ft}	
0 (Ref.)	$f_c = 15.34 f_{st} - 28.26$	(R ² =0.98)	$f_c = 16.92 f_{ft} - 55.70$	(R ² =0.99)
0.1	$f_c = 15.38 f_{st} - 28.60$		$f_c = 19.13 f_{ft} - 72.70$	$(R^2=0.99)$
0.3	$f_c = 15.00 f_{st} - 27.05$		$f_c = 17.63 f_{ft} - 65.96$	$(R^2=0.99)$
0.5	$f_c = 13.37 f_{st} - 20.18$		$f_c = 12.74 f_{ft} - 40.92$	$(R^2=0.99)$
1			_	$(R^2=0.95)$
	$f_c = 11.81 f_{st} - 17.81$	(K-0.90)	$f_c = 12.71 f_{ft} - 59.46$	(K =0.93)

Graphical Relationship between Flexural and Splitting Tensile **Strengths**

Relations between splitting tensile strength and flexural strength of concrete specimens were also investigated, and regression analysis was carried out. Figure 2 gives this experimental data points and the linear relations between data points. Moreover given the empirical equations of these relations are shown in Table 3. Correlations of the equations are above 96% for proposed relations in Figure 2. With these equations, it can be possible to eliminate heavy beam specimens by estimating flexural strength from splitting tensile strength.

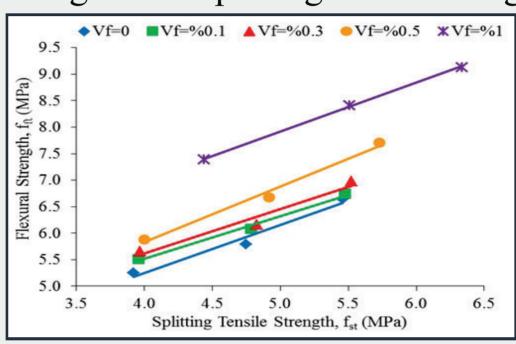


Figure 2. Relationship between splitting tensile and flexural strengths Table 3. Equations for the Relationship between Splitting Tensile and Flexural Strength

$V_f(\%)$	Equations for f_{ft} - f_{st}	
0 (Ref.)	$f_{ft} = 0.901 f_{st} + 1.650$	(R ² =0.97)
0.1	$f_{ft} = 0.806 f_{st} + 2.296$	$(R^2=0.99)$
0.3	$f_{ft} = 0.841 f_{st} + 2.253$	$(R^2=0.96)$
0.5	$f_{ft} = 1.051 f_{st} + 1.623$	(R ² =0.99)
1	$f_{ft} = 0.922 f_{st} + 3.311$	(R ² =0.99)

Analytical Relationship between Flexural and Splitting Tensile **Strengths**

As explained before, there is a relation between mechanical properties for each V_f value. In addition, it is well-known that increasing V_f value has an increasing effect on flexural strength of SFRC. Thus, for low volume fraction of steel fibers in this study, another relation can be revealed between flexural strength, splitting tensile strength and V_r . In this study, this analytical relation was written as equation (1) considering SFRC mixtures.

$$f_{ft} = 0.840 * f_{st} + 0.136 * V_f * f_{st} + 1.17 * V_f + 1.815 \text{ (MPa)}$$
 (1)

Here f_{tt} and f_{st} values are in MPa, and V_t is steel fiber volume fraction (%) With this relation, not only flexural strength can be predicted with splitting tensile strength, but also flexural strength values for different V_f values can be predicted. Considering a preliminary design and analysis of SFRC, this relation is very important. Revealed equation (1) in this study can estimate flexural tensile strength of SFRC for V_f values between 0.1~1%.

CONCLUSIONS

Considering the fact that increasing V_t provides higher flexural strength of SFRC, another relation was revealed between flexural strength, splitting tensile strength and V_f value changing between 0.1% and 1%. This relation is considered as an important conclusion of the study in terms of preliminary design and analysis of SFRC correctly. Furthermore, flexural and compressive strength values can be estimated for different V_f values by using one equation. Thus, both cube specimens for compressive strength and beam specimens for flexural strength test could be eliminated. As reducing number of specimens and tests, an economic and practical design process can be conducted for SFRC.

ACKNOWLEDGEMENTS: This research was supported by Fırat University Scientific Research Projects Unit (Grant No. MF.13.02 PhD Figure 1. Relationship between (a) compressive and splitting tensile, (b) Project and MF.13.29). Authors acknowledge to Kemerli Firm (Turkey) for their fiber material supports.







By Assist. Prof. Zeynep Basaran Bundur

About OzU

- ➤ Ozyegin University (OzU) was officially founded on May 18, 2007. The University currently has 225 full time faculty members and instructors within 5 Faculties; 3 Graduate Schools and 3 Schools.
- Faculty members are distinguishing researchers that 60% of them came from top 100 universities around the world.



Laboratory Infrastructure @

With 26 laboratories and 6 research centers with in its LEED certified campus, OzU offers sufficient lab infrastructure relevant to developing and analyzing novel techniques in cement-based materials.





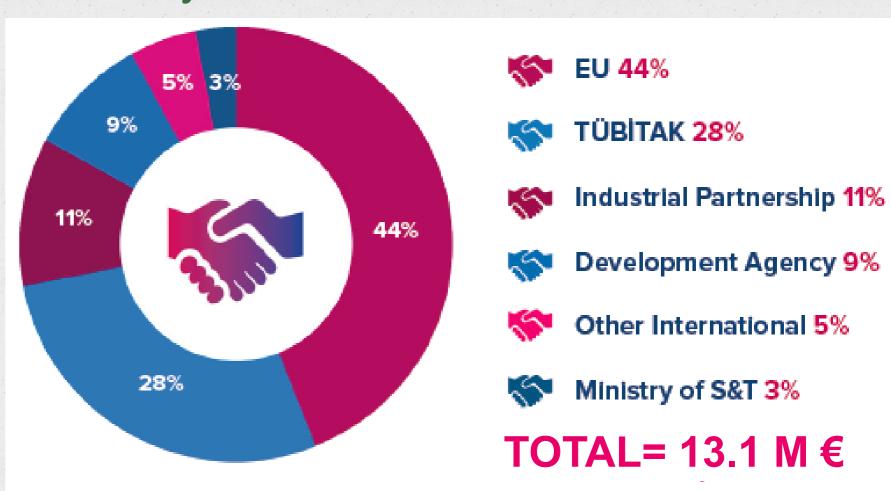


Technology Transfer Office @ OzU

- TTO works cordially with faculty members to carry out planning, development and management of research projects, development of industrial relations, innovation, technology transfer, and IP management.
- The main objective of the TTO at OZU is to assist research activities and innovation initiatives that aim to turn scientific and technological developments into social and economic benefits.

Research @ OzU

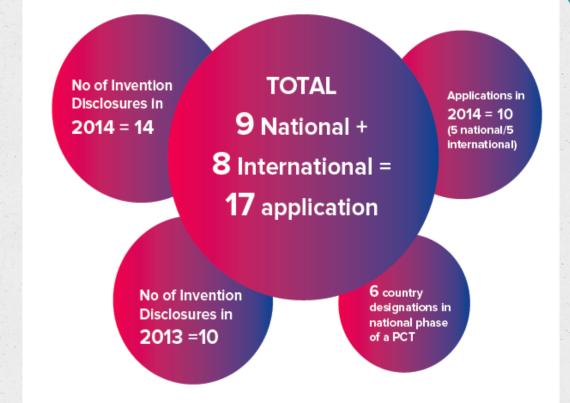
- As of September 2014, OzU hosted 17 FP7 Marie Curie Programme Projects (CIG and IIF), 3 FP7 projects. Apart from FP7, OzU takes part in other EU funding opportunities such as COST, CIP, etc.
- These EC grants' budget constitutes about 40% of the total grants budget of the University.



- The number of the on-going TUBITAK projects is exceeding 40 and most of them are research projects.
- ➤ OzU has recently been active in approximately 50 projects collaborated with world-known industries such as AirTies, DHL, Ericsson, etc. and leading national industrial institutions.

Patents @ OzU

Total number of 10 new patent applications were filed in 2014.



 OzU encourages interdisciplinary research activities. Its entrepreneurial environment allows faculty members to access complementary skills and experience.











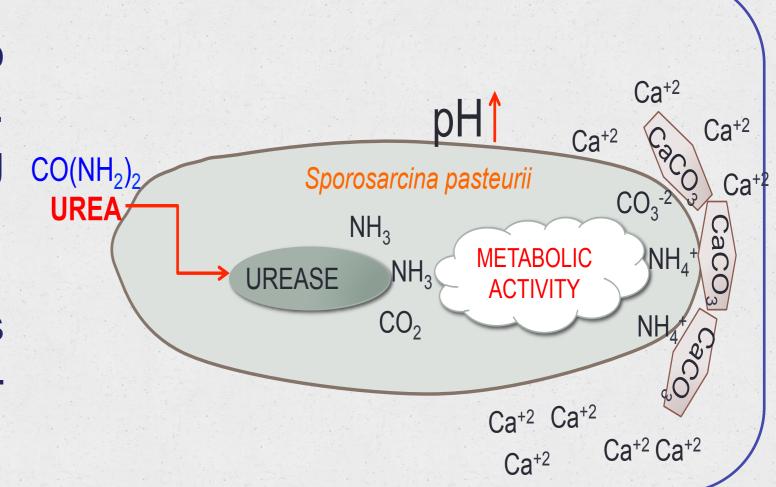




Use of biomineralization for self-healing mortar Primary Investigator: Assist. Prof. Zeynep Basaran Bundur MSc. Candidate: Ali Amiri

INTRODUCTION

- Recent research in the field proposes that it might be possible to develop a smart, cement-based material that can self-heal itself. Use of biomineralization is a novel technique to provide self-healing in cement-based materials.
- ➤ Biomineralization is a biochemical process in which microorganisms stimulate the formation of calcium carbonate (CaCO₃) and self-healing is obtained by sealing of the cracks with CaCO₃.



GOAL of BioConc

To analyze the self-healing of microcracks on mortar via biomineralization

An *original project* focuses on:

- Evaluation of the interaction among biomineralization, microorganism growth and AEA
- ➤ Investigating the influence of microorganisms on workability of cement based materials
- Incorporation of AEA to improve the self-healing ability
- ➤ Investigation of the interfacial transition zone between MICC and crack surface
- ➤ Evaluation of the durability of CaCO₃ precipitate under weathering conditions (rain, freezing, sun exposure... etc.)

RESEARCH STAGES

STEP 1. Development of a bacterial self-healing admixture:

- Determining the optimum conditions for growth and biomineralization

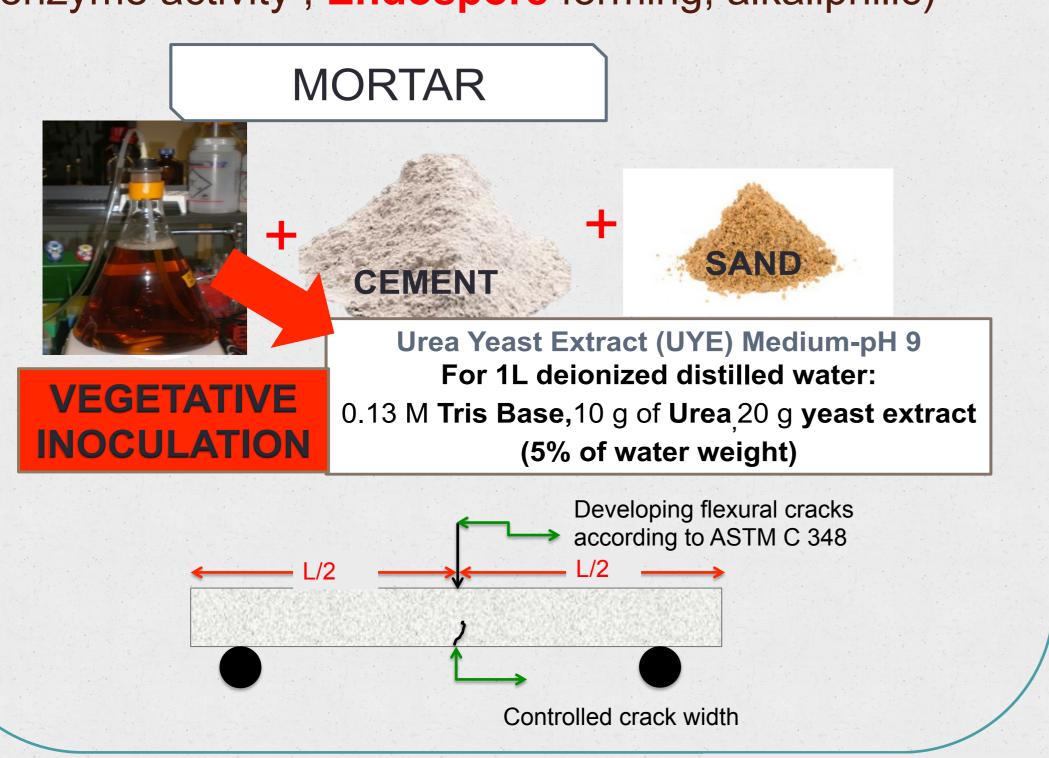


STEP 2. Incorporation of bacterial admixture in mortar

- Testing the influence of the admixture on performance on mortar

OUR APPROACH

NCTC 4822 Sporosarcina pasteurii (High Urease enzyme activity; Endospore forming; alkaliphilic)



STEP 3. Testing the efficiency of bacterial admixture on self-healing mortar:

- Analyzing the flexural strength healing and the bonding of the precipitate on crack surface

STEP 4. Testing the durability of bacterial CaCO₃ sealant under weathering conditions/

ACKNOWLEDGEMENT

This research is fundedwithin the Career Development Program by The Scientific and Technological Research Council of Turkey (TUBITAK 3501; award no: 114M308).











T. ALTUĞ SÖYLEV, ALMILA UZEL, NESRİN YARDIMCI

EFFECT of DIFFERENT REGIONAL CLIMATIC CONDITIONS to THE CORROSION of REINFORCED CONCRETE STRUCTURES NEAR TO OR ON THE COAST

Comparison between Black Sea-Rize and Mediterranean (Aegean) Sea-İzmir Coastal Atmospheric Conditions

Temperature, °C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Izmir	19	14	11	9	10	12	16	21	26	28	28	24
Rize	16	12	8	7	7	8	12	16	20	23	23	20

Relative Humidity, %

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
								59				
Rize	75	71	70	73	71	73	79	80	78	75	74	74

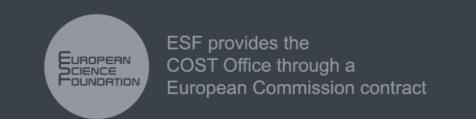
Total Monthly Precipitation, kg/m²

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Izmir	44	195	144	121	102	74	47	29	8	2	2	16
Rize	284	252	242	221	180	153	95	98	134	148	184	250

Concrete Standard EN 206 specifies a single limit value of concrete quality for corrosion protection at all coastal zones!

IS THIS CONCRETE QUALITY SATISFACTORY FOR ALL COASTAL ZONES WITH SUCH DIFFERENT ATMOSPHERIC CONDITIONS? The present research study will try to find the answer with site measurements and laboratory simulations.











Kiev National University of Civil Engineering and Architecture

V.D. Glukhovsky Scientific Research Institute for Binders and Materials (SRIBM)



www.knuba.edu.ua

Potential self developed advanced testing techniques used to evaluate properties of cement-based materials and concrete structures

- Modelling of a thermo stressed state of concrete with the help of the tailor-made software product "ELCUT" based on a finite elements
 method, analysis of temperature gradients and thermal stresses of the freshly laid concrete and during its hardening and under various
 temperature conditions.
- Modelling of crack resistance of concrete by plotting load-deformation diagrams of concrete with a specially made crack in the "load-deflection" coordinates until its failure for further qualitative analysis of crack resistance of concrete before occurrence of critical (until macrocracking) and after occurrence of critical (macrocrack propagation) stages of deformation (in collaboration with Lviv Polytechnic National University, Ukraine).

Presentation of recent and most important scientific/research projects related to the COST Action TU1404

□ 2008-2011: Concrete Studies (New Safe Confinement at the Chernobyl nuclear power plant). Sub-contract Agreement with Consortium NOVARKA - NSC Project (JV Bouygues TP & Vinci Construction Grands Projets).

Tasks performed related to this COST Action - WG 1:

Analysis, development of concrete requirements and specifications. Development of methodology for concrete mix development and approval recommendations and validation of concrete production, transport, placing and curing conditions. Qualification of raw materials for concrete. Concrete mixes design in laboratory - Compliance and sensitivity study. Plant trials and adjustment of concrete mixes final report on concrete studies.

Tasks performed related to this COST Action - WG2:

- Simulation of thermo stressed state of the concrete for different cross-sections of the structure massive foundations
- Development of heat evolution model (calculation of temperature fields within massive concrete) as variable of time and temperature and check of its adequacy/compliance.
- Simulation of thermo stressed states in the reinforced concrete massive with definition of critical values, selection of control measurement points and appointment of measurement frequency. By using the model, determination of parameters for direct regulation (diameters, quantity and disposition of pipes, temperature and required volume of water to be pumped) and for passive regulation (parameters of insulation, cooling of the concrete mix, etc.) of thermo stressed state of the reinforced concrete for summer period
- Study the degradation of concrete for massive foundations for NSC due to aggressive environmental influences, and the development of mathematical models of concrete degradation for 100 years. NOVARKA NSC Project.
 Scientific verify the 100 years durability of the concrete. Definition major aggressive environmental influences on concrete in accordance to DSTU B V.2.7-176:2008 (EN 206-1:2000, NEQ). Definition of degradation a concrete via laboratory trials. Development a numerical model for the evolution of the concrete degradation after 100 years and verify the following characteristics of the concrete after 100 years: evolution of the carbonization of the concrete; behavior of the concrete under cyclic freezing/thawing; combined effect of the carbonization and cyclic freezing/thawing.

<u>Outcome</u>: By using the model, determination of parameters for direct regulation (diameters, quantity and disposition of pipes, temperature and required volume of water to be pumped, parameters of electric heating, etc.) and for passive regulation (parameters of insulation, heating of the concrete mix, etc.) of thermo stressed state of the reinforced concrete for winter period. Analysis of crack potentiality for summer and winter conditions.

□ 2011: Analysis of thermo stressed state of the foundation "Social & Civic Complex Ocean Plaza". Development of recommendations for passive regulation of thermo stressed state and monitoring temperature regime of hardening concrete. "KAN Development". Kiev, Ukraine.

<u>Tasks performed related to this COST Action - WG2:</u> Simulation of thermo stressed states in the reinforced concrete foundation. By using the model, determination of parameters for passive regulation of thermo stressed state of the reinforced concrete, and analysis its crack potential. Monitoring and regulation thermo stressed state of concrete foundation.

□ 2012: Modelling and monitoring of thermo stressed state of concrete foundation of the public center. "Ant Yapi", Kiev, Ukraine.

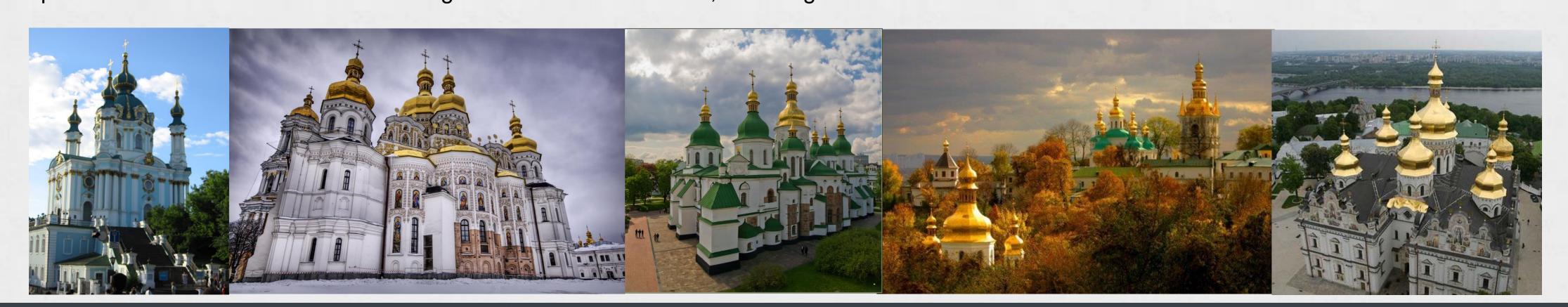
<u>Tasks performed related to this COST Action - WG2:</u> Simulation of thermo stressed states of the reinforced concrete foundation (15000 m³), selection of control measurement points and appointment of measurement frequency. By using the model, determination of parameters insulation reinforced concrete, and analysis its crack potentiality. Monitoring and regulation thermo stressed state of concrete foundation.

A list of recent and most important scientific/research papers related to the COST Action

1. Krivenko P. et al Physical and chemical properties of adhesives based on geocement for restoration and rehabilitation of building, Advanced_Materials Research, 2013, Vol. 688, 123–129 (www.scientific.net/AMR.688.123); 2. Krivenko P. et al Features of Alkali-Activated Slag Portland, 1-st Int. Conference on the Chemistry of Construction Materials – Berlin, October 7-9, 2013, 453-456; 3. RILEM State-of-The-Art Report "Alkali Activated Materials", 2014; 4. Krivenko P.V. et al Modeling a thermo-stressed state of the cast-in-situ low carbon footprint alkali activated slag cement concrete hardened under hot environment, Applied Mechanics and Materials. 2014. Vol.525, 482–490 (www.scientific.net/AMM.525.482); 5. Troyan V., Krivenko P. Prediction of durability of plasticized concrete. 1st Int. Conference on the Chemistry of Construction Materials October 7-9, 2013, Berlin, Germany, 355 – 358; 6. R. Runova, I. Rudenko, V. Troyan, High-Performance Concrete for massive structures,18. Ibausil. Int. Baustofftagung. Weimar, Deutschland, September 12-15, 2012. Tagungsbericht, Band 2, 2-0082 – 2-0089; 7. Solodky S.Y. et al. Numerical Modelling and Optimization of Building Composites. Text-book, Lvov, 2006; 8. Solodky S.Y. et al. Evaluation of a Thermostressed State of Road Pavings at Early Stages of Hardening of Cement Concrete, Journal Avtoshljahovil Ukrainy, 2015 (in print).

Possible open positions for STSM

Exchange of experience in the field of durability testing of cement-based materials and modelling, test methods related to durability parameters specified in national standards for testing cement-based materials, including alkali-activated cement-based materials.











David Dunne, AECOM

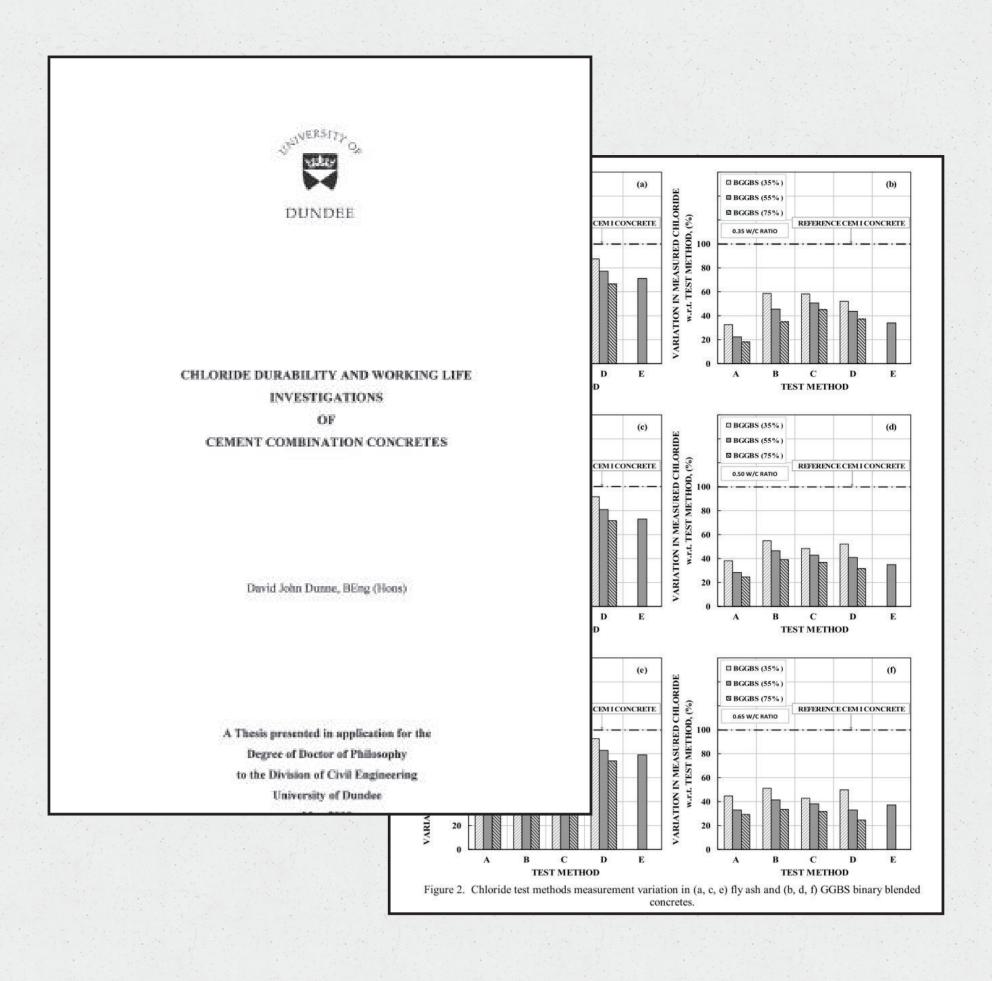
David is a Senior Engineer at AECOM. He has a PhD in Concrete Technology, specialising in the durability of reinforced concrete and concrete standards. He is one of AECOM's concrete specialists and is a member of their international materials group. He is also an AECOM industrial supervisor at Loughborough University, Centre for Innovative and Collaborative Construction Engineering and a Member of the Civil Engineering Research Association of Ireland.

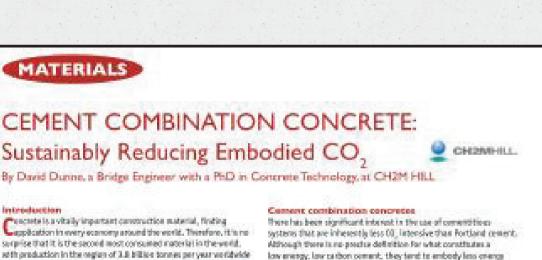
Selected Publications

Dunne D.J. Chloride Durability and Working Life Investigations of Cement Combination Concretes. PhD Thesis, University of Dundee, Scotland, May 2010, p314.

Dunne, D.J. McKenna, P, Newlands, M.D. and Waite, A. Cement Combination Concretes: Where Less Cement is More. 15th Concrete, Materials & Conservation Conference at STRUCTURAL FAULTS + REPAIR-2014, 9th - 10th July 2014, Imperial College, University of London, Kensington, London, UK.

Collery, D., McKenna, P. and Dunne, D.J. Optimising Available Resources and Driving Sustainability within the Construction Industry with the use of Recycled Aggregates Fines. 1st Civil Engineering Research Association of Ireland Conference (CERIA 2014), 28th - 29th August 2014, Queen's University Belfast, Belfast, Northern Ireland.





and some 22.5 million or in the UK alone". There is now international tenand for less wastage of material, as well as the need for reductions. in pollution from the construction industry as a whole. Concrete is one of the most sustainable building materials, taking nto consideration its local nature, the energy consumed during a manufacture and its energy performance over the lifetime of structure). Cement is an essential impredient in the makeup of concrete and is as vital a construction material. This material bus. vaviances, where producing one torrie of Perfland correct (CEN), is reported to release an equivalent quantity of carbon-dioxide 00.) Into the stroophers. In 2012, the production of a standardised taken of concrete produced 79.44/a CO.1. Our weed to address this environmental issue is becoming insreasingly acute, as the enriches FCD, and other gases into the atmosphere is predominantly blamed. for global worming and climate change.

Partiand cement (CDF I), a material containing quantities of caldium compounds, sitios, alamina and from exide, involves the blending of litroestone or chall with cary or shale. This mixture is then heated in a notary Min at a temperature in the region of 1450°C. At these temperatures, a chemical change occurs where the new materials turn nto a hant, nodular saild known as clinker. After cooling, the clinker

is ground in a ball, or roller will and calcium sulphate is then added.

the control its setting time) to produce cement powder. Overall, this

process is energy demanding with CO, emitted as chemical changes. inservation of natural resources and the primotion of sustainable development is a major topic with environmentalists and politicisms who are focused on reducing CD, emissions. In response to this, the concrete industry is fully entiracing a sustainability agenda that he construction industry is working towards. They are reducing dinker contents, embodied energy and 00, emissions associates with concrete production. This is being undertaken in order to refine

economics, improve the societal impact of concrete and to ensure ton-Pertiand cements Improvements in Portland coment production procedures are only me step in the drive to improve the sustainability of concrets. As result. I number of materials have been developed to replace Portland cement, These non-Portland based cements include:

peopelymenic, law energy CSA-belifte cements, cements based onragnetium out to derived from carbonate or discates and exp-cement ased on municipal solid waste indiversion ash. A number Prechalcal and commercial barriers currently exist, preventing

their subsensitic inclusion in the construction industry. These i) difficulty in resentacturing in high valueses. sesociated costs () unproven long-term performance in concrete

I be loads are unlikely to occur in the shart/medium-term due to the scale of the spesations regained and manufacturing involved. BUILDING ENGINEER December 2013

low energy, law parthon persent, they tend to embody less evenus they should esshody less energy than traditional Portland.

and emittless CO, during manufacturing than Portland cement. The Mineral Products Association (MPA) recommends that these concretes should typically possess some or all of the following: coments. Including those that contain additional inorganic/ mineral constituents they should be manufactured using a nevel process that ideally utilises wante-derived feels and raw materials.

 they would be expected to vehice both waste and emissions, in particular the greenhouse carbon clouds. In response to these goals, a turge of addition materials are now available for use in concrete production in the UK. These are waste by-product materials derived from other industrial activities. These materials include national popularies (fly sels, elitics furier metakaolimi, artificial pegolamas (ground granulated Marthurnace stage, and latent hydraelic non-reactive materials (timestone). These marterials can be added separately at the concrete relear, where they are termed as "additions". They can also be incorporated into factor, produced remest where they are termed as 'compacity consents'. In both cases a percentage of the PC (CDAD) content is replaced. Addition materials are not a new concept. British Standards covering the inclusion of different addition materials are as follows: fly ash-(1920s); ggbs (1960s); timestone (1990s); stilca fume (2000s) and metakactin (not standardized but covered in 83.6% 197-1). Plore recently, RS FM 197-1, the purient rement standard applicable to LIK concrete production, specifies 27 products in the family of common

environments". These standards have gaved the way for greater analyzation of addition materials in UK convents production allowing net asky binary but terrary and gusternary generit combinations to be used in concrete production. Addition materials for use in UK coment constinution concretes

BS EN 397-1 persont that are suitable for use in UK flocal.

presents*, 85 8500-1:2006*A1:2012, recommends the types of

Concert combinations consist of CEM I with pertial replacement by a percentage shan 'addition material'. Application of these materials to binary (CEM I + one addition material) and tomary (CEM I + 2 addition materials), combinations will reduce the quantity of CO. produced. This is actrieved by netracing the dependency on CEN I production and reducing the need to use virgin new materials. It would be advantageous at this stage to describe the addition materials that are mentioned above and discussed within following sections.

Fly ask (FA): A by-product of the dry combustion of coal-fined furnaces used for electricity generation. Coal is supplied to a Farmace at temperatures of L150°C, where carbon in the coal is ignited. The non-combustible minerals in the coal become reactive due to the formation of amorphous sitics in the coal-fixed furnace. High calcium to ask passesses converting properties whereas law colclum fly sals possesses pozenta-nic preperties.

Realising real innovation from R&D

RESEARCH AND DEVELOPMENT

Real innovation of research and development lies in directly linking and integrating research activities with industry requirements. as David Dunne and Christian Christodoudou of ADCOM discuss.

hills supporting and describeing a highly slotted workforce, research and development is an important driver in supporting the someonic growth. to materate to be improve on current technologies, develop ismoustions and strengthen the marketplace. Collectively, the UK is a high achiever in R&D and subsequently innovation, as a recent report article and ritation output per visuanther or per unit of B&D expenditure. Arrang its operator countries, the UK is ranked from by field-weighted citation impact, which is an

In 2013, there was a significant increase in graduate recruitment by the LR construction industry, Flowerec, it is acknowledged, "that there is a shortage of suitable qualified young people to deliver the tectorically complex and time-critical challenges in the years about 10 The Industry requires highly innevative people and technologies if it is to successfully mounts challenging projects. Historically, these factors have not been perceived as ratios contributure of commercial advantage Marrower, in the past, technology was primarily perceived as a means for improving operational efficiency. This is because innovations are often project driven and

equired on a project-by-project basis. This view is now-changing, with R&D-suspot, competitiveness while retaining operational efficiencies, hydred, there are examples of where the industry is currently adopting R&D and incomative thinking, these include:

Crossnot of the Tunnelling and Underground Construction Academy, a purpose-built facility providing training

in the key skills required to work in the often the result of B&D. This can engerder and - as has been established by LU - can Isosophu procurement – in April 2012 successfully reduce costs while sufarlying London Underground (LE) faunched its "Innovative Contractor Engagement" One of the main innovations in givil process, glacing quality and immersion engineering research is in the area of ahead of post. This process serv

restorial science. As scientific and technical advances are made, numerous new materials unsuccessful benders compensated for have been developed and many can be applied. their endowears. This process resulted in a 50% increase in the long-term to construction. elient outtheneft ratio for the Bank. Concrete in particular plans a gracial role Station upgrade project.

• Educational institutions – the first new in today's construction inclustry and is rightly placed as being the most widely used manharther of earliest college to be made material in the world. Consequently, incorporated in 20 years, is planned for this provides suppliers and end coors with High Speed 2 (HSZ), This will educate a plentiful insentire to sent and develop. skelled southfurce to build HSZ along exepective new and improved forms will other infrastructure projects in the The our liest wide scale users of a calcinnal UK. In addition, the UK Ornhore. Operations Group-is convently surging John Smeaton is credited with reaking the the Government to establish a similar froi madern concrete (hydraulic content) by adding pubbles as a course aggregate institution to develop skills for the

fracking reductry. Noting these changes in mind-set, a sumber of Surriers nemain that prevent the unitraction industry from committing bother to R&D and immediation. These

. In a profit-driven environment, there is an unwillingness to invest in tasks that do not show signs of immediate profit. + New and sometimes approved technologies can carry some residual. . In the immediate luture, lossest price

processes even with the advent of the

Bank Station procurement process

success. While this is one example of where the namely chain is prepared to: programment is not set to keed highly. innovative research. Instonation is a constructly referenced

contractors and suppliers. Innovation involves the application of new solutions that

in the production of maders sky concerts. Entorsising good RAD, modern concrete. eractical involvations, which include: greater chalces to design concretes to satisfy specific performance criteria.

for corrosion is estimated to lie somewhere

binder, which is reflected within the current

formation of the European Standards

for reinforced concrete durability. This

Thereafter, the need to harmonise both

Codes in order to promote a performance

Michael Grantham of Sandberg discussed

determine chloride transport parameters in 'Laboratory Methods to Determine Chloride

laboratory test methods that are used to

Transport Parameters'. He outlined how

the mechanisms of ingress can consist of absorption, permeation or diffusion, with

tension, pressure or concentration gradient.

derive, in characterising the performance of

Discussions of immersion and migration test methods, and how they can be used to

evaluate alternative concrete mix designs at

with respect to in-situ structures, it was noted

that the determination of chloride ion profiles

is key to evaluating the corrosion potential of

steel reinforcement. Lastly, it was noted that

these multi-point chloride contents can be

the design stage, were presented. However,

concrete in resisting chloride ingress, was

Both natural and electrically accelerated

the driving force consisting of surface

test methods were discussed and the

usefulness of the measurements they

summarised.

highlighted how chloride durability

specification to BS 8500-1(1) and the

stimulated great debate.

Standards.

and mixing providend brick into concret.

Subsequently, Joseph Aspelin (1824) has been

credited with inventing the dismission correct

used in concrete production today, namely

Portland coment (PC). While noting modern

day developments - such as generolymen.

beating concrete and NoveCern, to name a

New - the majority of measurch linto conclust

A high proportion of this research has aurrounded the repressful, re-ingineering

of PC to improve its sustainability and

remitte-life performance characteristics. One coumple of where this B&D has had

a direct link-up with industry and where

research findings here been integrated

into the industry, is through the use of

along with recorded secondary and

waste by product reaterials. Natable, this

manufactured aggregates, applied reutinal

has been of an innovative mature.

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DURABILITY/AGGRESSIVE ENVIRONMENTS

Working towards chloride durability performance specification

test method for use by the European.

* joint weeking groups are now

demonstrated how industry and

The use of additions such as fly ash and GGBS in concretes is known to be favourable in achieving specific concrete performance criteria. However, at what stage, if at all, does the use of these materials have a negative effect on certain properties, such as, resistance to chloride ion ingress? David Dunne of AECOM and Morse Newtands of the Concrete Technology Unit at the University of Dundon, review the findings of a research project into this topic, undertaken at Dundee.

collaborating to cover dambility and service life design. there are origining proposals to develop 'chloride resistant classes', for use serves Europe

• there is now the Model Cade for service life design proposed by 697. More recently, the importance of this durability issue was discussed by the Institute of Concrete Technology (ICT), where presentations were given on tespractice models. This ICT sentings

 he differide ingress of conceets. continues to be a 'not topic' inrelation to the dumblish of reinforced concrete structures. The importance of the issue is only heightened at für repean and sternational level, where:

agree on standardising a single chloride fragmented. Taking this Emitation into

Blended cereent concretes in general, while the introduction of excers occurrent Standard BS EN 190 100 puved the way for a veider is lection of ment types to be applied in concrete . there is now real potential for Europe to production, passarch in this field has been

academia are collaborating to forther exposure emirantments, covering the investigate this long-standing diriorida sunge of exposure conditions specified in BS 8300°C. Pleasurements of chieride ingress, total and free chloride contents and rates were insestigated for adaptive

concretes across the three common treatal exposures, while certasion monitoring was also . The final stage of the research project estimated the working lives of a

account, the current project investigated the

chioride durability and subsequent working

consent concretes. In meeting the messarch

number of main states, which consisted of

objectives, the programme was divided into a

· Establishing the suitability of a range of

contemporary chloridic test methods, to

acceptable measure obloride ingress of

ingress properties of a range of different.

concrete. These methods were then

applied in establishing the chloride

concrete types, which encompassed

both hinary and termons blended

· Establishing the performance of

concretes in airealated chloride

life probabilities of a samp of blended.

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Chloride transport in concrete: specification, testing and modelling form. As illustrated in Figure 2, the threshol

CONCRETE DURABILITY

The Institute of Concrete Technolog (ICT) held a half-day seminar in September 2014 on 'Chloride Transport in Concrete', Chris **Goodier of Loughborough University** and David Dunne of AECOM report.

the concrete industry, that the nost common and serious cause of is corrosion of reinforcing steel induced by chloride ion ingress and oxygen ingress into reinforced concrete.

Therefore, any improvement in the reliability of predicting the timing and the extent of required maintenance will result in considerable cost savings. Developments in test methods and reliability modelling of chloride transport through the concrete cover, an essential part of any life-time prediction model, are of ongoing concern to concrete technologists. Owing to the severity of this issue, the ICT held a half-day seminar at University College London in September 2014, to discuss this topic. Six papers were presented by leading academic and industrial experts. The topics examined the latest research and industrial

case studies on the testing and modelling of chloride transport in concrete, including: performance specification of concrete in chloride environments · laboratory methods to determine chloride transport parameters

· site methods for assessing the chloride transport resistance of concrete

Passive oxide layer on steel

implications to service life predictions · chloride durability industrial case · challenges for characterisation of chloride transport of novel cement

Steel in a moist concrete is protected against solution in the concrete. At these high pH levels, a passive film of ferric oxide forms on further corrosion (Figure 1). This ferric oxide layer can be damaged as a result of reduced presence of chloride ions. Chloride ions can be present in concrete as a result of the application of de-icing salts, exposure to a marine environment, airborne added as an accelerator to the concrete).

salt, or from the concrete constituents (eg, historical application of calcium chloride As a consequence of corrosion problems in service, most countries now prohibit the use of calcium chloride in reinforced and prestressed concrete. In Europe, the maximum permissible total chloride ion levels in fresh concrete are 0.4% (by % weight of cement) for reinforced concrete and 0.1% for prestressed concrete. These limits apply irrespective of whether or not the concrete is exposed to external chlorides. Once corrosion has commenced, the rate of corrosion is controlled by the ease at which oxygen enters the concrete and by the availability of moisture. The corrosion product that forms has a volume two to four times the volume of steel before it oxidises. Thus internal stresses can be induced in the concrete, eventually leading to cracking along the lines of the reinforcement, spalling

in the serviceability of a structural member. Performance specification In his presentation, 'Performance Specification of Concrete in Chloride Environments', John Broomfield discussed how the corrosion of steel in water solution was a function of hydroxide ion (OH-) concentration and pH level. He noted that chloride ions do not significantly affect the concrete chemistry, but at the steel surface they compete with OH- ions, that are vital

to the formation of the passive layer. In areas

where voids in cement paste exist and OHconcentrations are low, corrosive pits can

of the concrete, loss of bond and reductions

used to generate a chloride profile. Thereafter, by a process of non-linear curve-fitting of this profile to Fick's second law of diffusion. surface chlorides and a diffusion coefficient can be obtained. This coefficient can then be used in a 'service life model' for the structure and to estimate the time for chloride to reach the steel 'initiation period'. Muhammed Basheer of the University of Leeds explained in ('Site Methods for Assessing the Chloride Transport Resistance of Concrete') how an electric field hastens the ingress of chloride ions. Here it was outlined

how this knowledge can be applied to carry

out in-situ accelerated chloride migration

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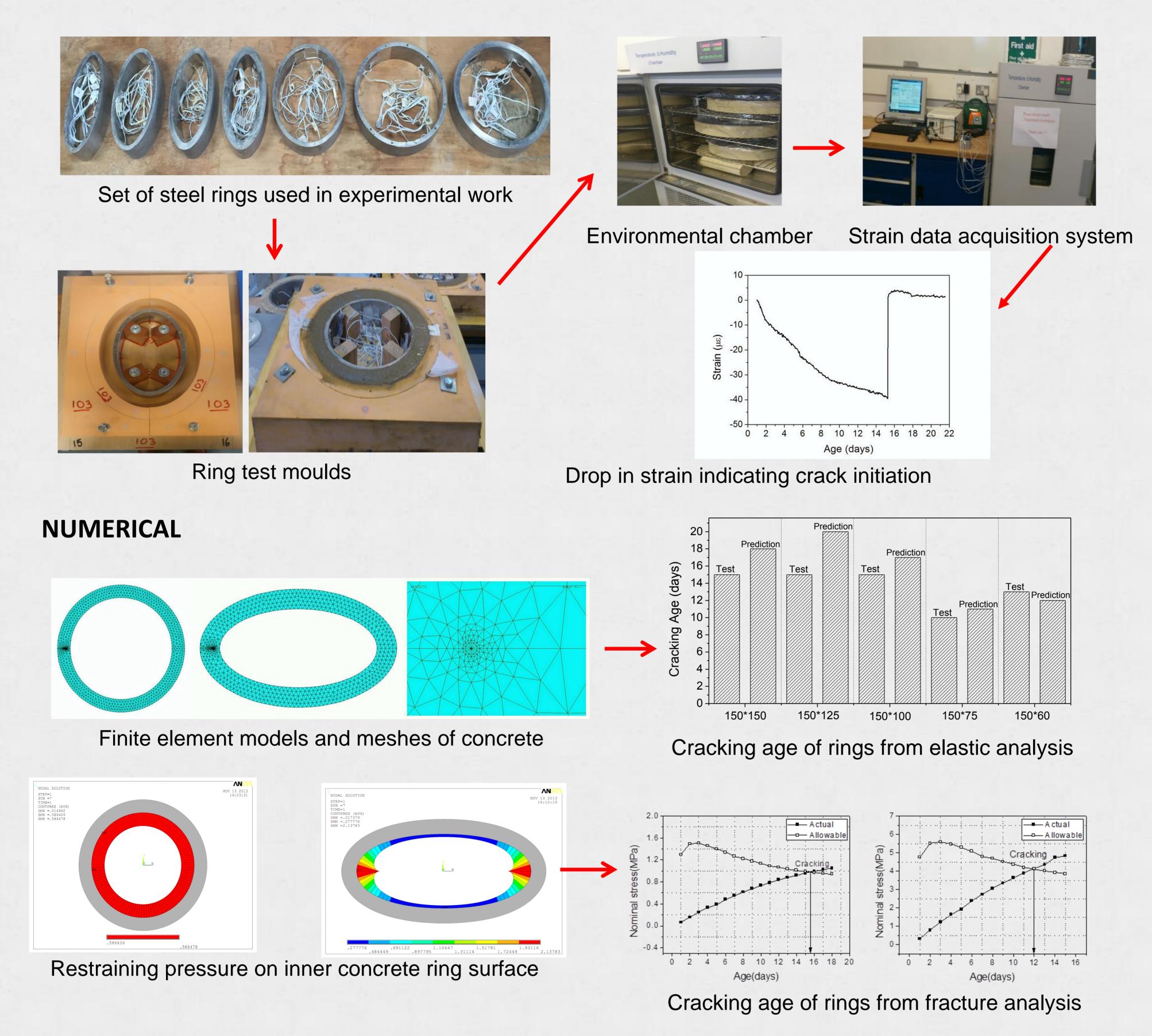
Towards Assessment of Restrained Shrinkage Cracking of Cement-based Materials using Elliptical Ring Specimens

Dr Xiangming Zhou, Brunel University London

Restrained shrinkage cracking of concrete can affect serviceability, durability, and load carrying capacity of concrete structures. Ring test has been widely used for assessing restrained shrinkage cracking of concrete, such as the AASHTO T 334-08 thick ring test & the ASTM C 1581/C 1581M – 09a thin ring test. The ring test methods are simple to use but have a low degree of restraint, resulting in a fairly long time before a crack initiates. It is also impossible to predict crack position.

The elliptical geometry enables stress concentration therefore shortens ring test duration. Crack position is predictable due to the stress concentration generated around the vertices. This research is therefore to prove elliptical ring test both experimentally & numerically by mapping circular ring test. The ultimate target is to proposed an EN standard elliptical ring test method for assessing cracking potential of concrete or other cement-based materials.

EXPERIMENTAL



CONCLUSIONS

- There are multiple cracks in a restrained elliptical ring but only one crack in a circular ring.
- Crack position depends on the degree of restraint in a concrete ring. The geometrical factor a/b of an elliptical ring largely determines the degree of restraint.
- When a/b =2~3, elliptical thin ring cracks earlier than circular ring. In this case, circular ring test can be replaced by elliptical ring test.

ACKNOWLEDGEMENT













