Exploring Machine Learning to Predict Concrete Field Performance Against Alkali-Aggregate Reaction (AAR)

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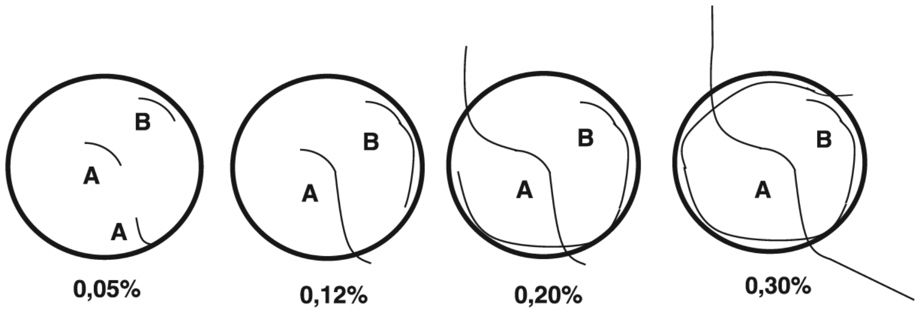
µStructure

Introduction

Aggregate mineralogy

Alkali hydroxide content

Environmental conditions



REF: Sanchez et al (2015)

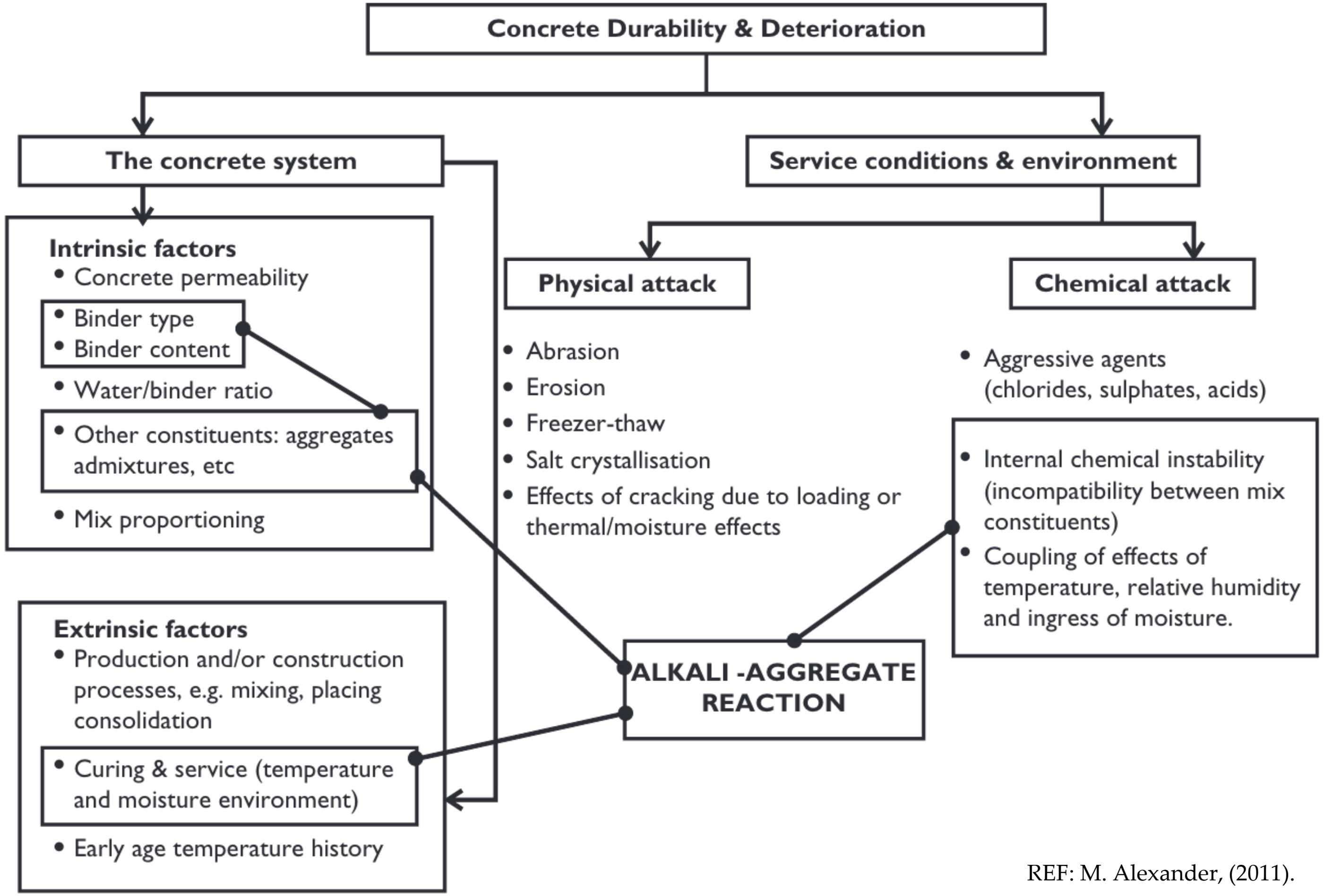
Classification of the damage degree in concrete due to ASR.

Classification of ASR damage degree (%)	Reference expansion level (%)[a]	Assessment of ASR				
		Stiffness loss (%)	Compressive strength loss (%)	Tensile strength loss (%)	SDI	DRI
Negligible	0.00–0.03	–	–	–	0.06–0.16	100–155
Marginal	0.04 ± 0.01	5–37	(−)10–15	15–60	0.11–0.25	210–400
Moderate	0.11 ± 0.01	20–50	0–20	40–65	0.15–0.31	330–500
High	0.20 ± 0.01	35–60	13–25	45–80	0.19–0.32	500–765
Very high	0.30 ± 0.01	40–67	20–35		0.22–0.36	600–925

[a] These levels of expansion should not be considered as strict limits between the various classes of damage degree but more as indicators/reference levels for which comparative analysis of petrographic and mechanical data was carried out allowing to highlight significant damage levels in concrete due to the progress of ASR.

REF: Sanchez et al (2017)

Background



REF: M. Alexander, (2011).

Laboratory testing

Procedure	Sample		Test Conditions		Test duration
	Shape	Size	Temperature	Storage	
Accelerated Mortar Bar Test – AMBT – (RILEM AAR-2.1)	Prism	25x25x285mm^3	80ºC	Samples immersed in a 1M NaOH solution	14 days
Accelerated Mortar Bar Test – AMBT – (RILEM AAR-2.2 / ASTM C1260-22 / AS 1141.60.1)	Prism	40x40x160mm^3	80ºC	Samples immersed in a 1M NaOH solution	14 days
Concrete Prism Test – CPT – (RILEM AAR-3 / CSA A23.2-14A / AS 1141.60.2)	Prism	75x75x250mm^3	38ºC	RH>95%	52 weeks
Accelerated Concrete Prism Test – ACPT – (RILEM AAR-4 / RILEM AAR-11 / ASTM C1293)	Prism	75x75x250mm^3	60°C	RH>95%	20 weeks
Concrete Microbar Test – CMBT – (RILEM AAR-5)	Prism	40x40x160mm^3	80ºC	Samples immersed in a 1M NaOH solution	14 days
Miniature concrete prism test – MCPT (AASHTO T380)	Prism	50x50x285mm^3	60ºC	Samples immersed in a 1M NaOH solution	56 days
Danish Mortar Bar Test – TI-B51	Prism	40x40x160mm^3	50ºC	Samples immersed in a 1M NaOH solution	52 weeks
Norwegian concrete prism test – NCPT – (RILEM AAR-10)	Prism	100×100×450mm^3	38ºC	RH>95%	52 weeks
Concrete Cylinder Test – CCT	Cylinder	ϕ100mm h=200mm	38ºC, 50ºC	RH>95%	15 weeks
German Concrete Method – GCM	Prism Cube	100x100x450mm^3 300x300x300mm^3	40°C	Samples storage in fog chambers	9 months
Alkali-Wrapped Concrete Prism Test – AW-CPT – (RILEM AAR-13)	This procedure can be combined with any of the above methods			Samples wrapped with water-holding material with alkali hydroxide solution (same as concrete pore solution)	

Reliability?

Objective

- How to predict long term field performance of concrete, based on laboratory tests and current data?

Laboratory

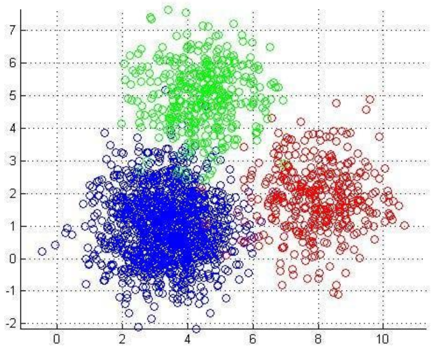
Field

Methodology

Bibliometric analysis

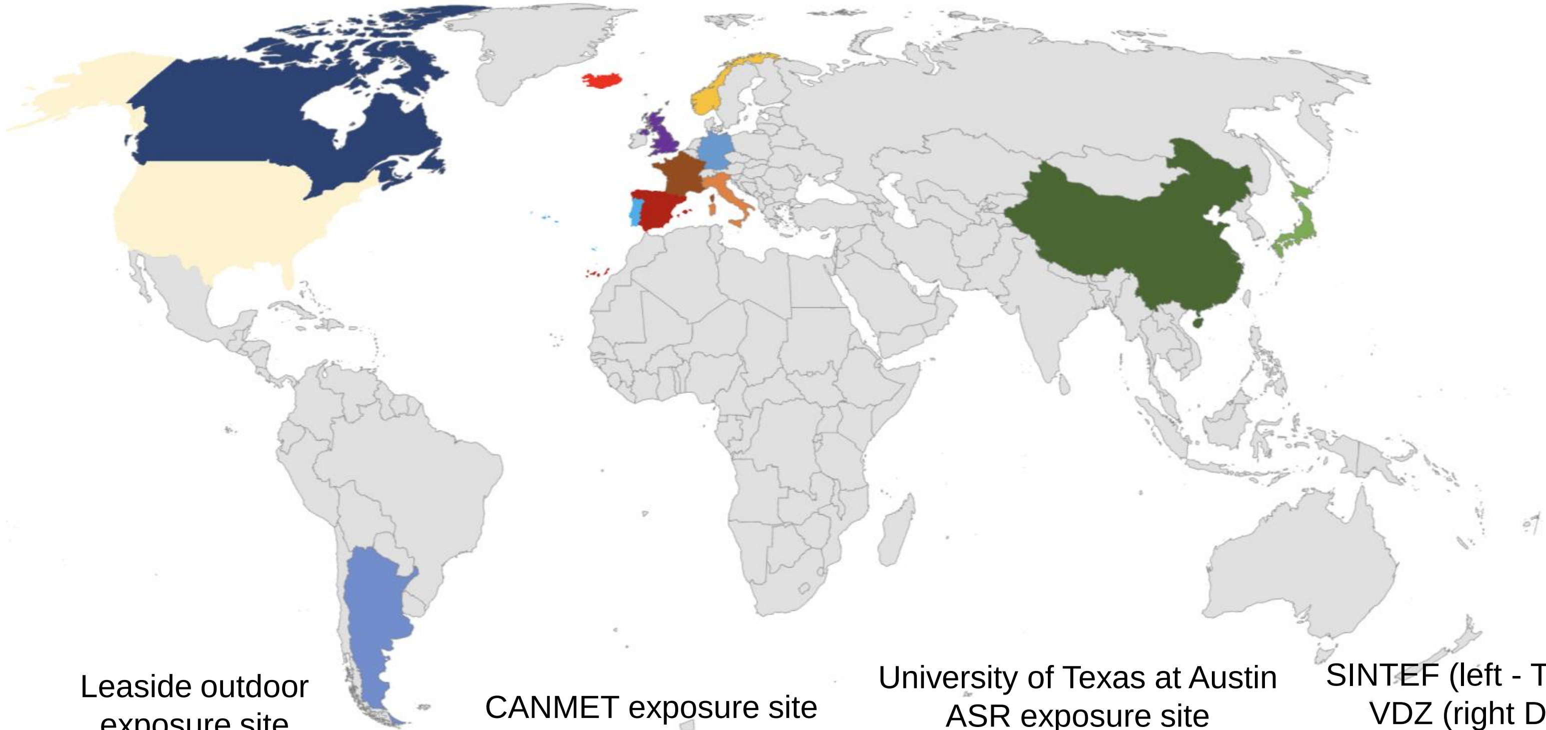
Bibliometric analysis

- Authorship connections / Collaborations
- Citation patterns
- Publication history
- Leading researchers
- Impact of a research topic
- Trends



Clustering

Preliminary results: field exposed blocks



Kingston outdoor exposure site

Treat Island cold water marine exposure site

MANNVIT exposure site

BRE sites in the UK

Leaside outdoor exposure site

CANMET exposure site

University of Texas at Austin ASR exposure site

SINTEF (left - Trondheim, Norway) and VDZ (right Düsseldorf, Germany)

COIN cubes on the LNEC exposure site in Lisbon (Portugal)

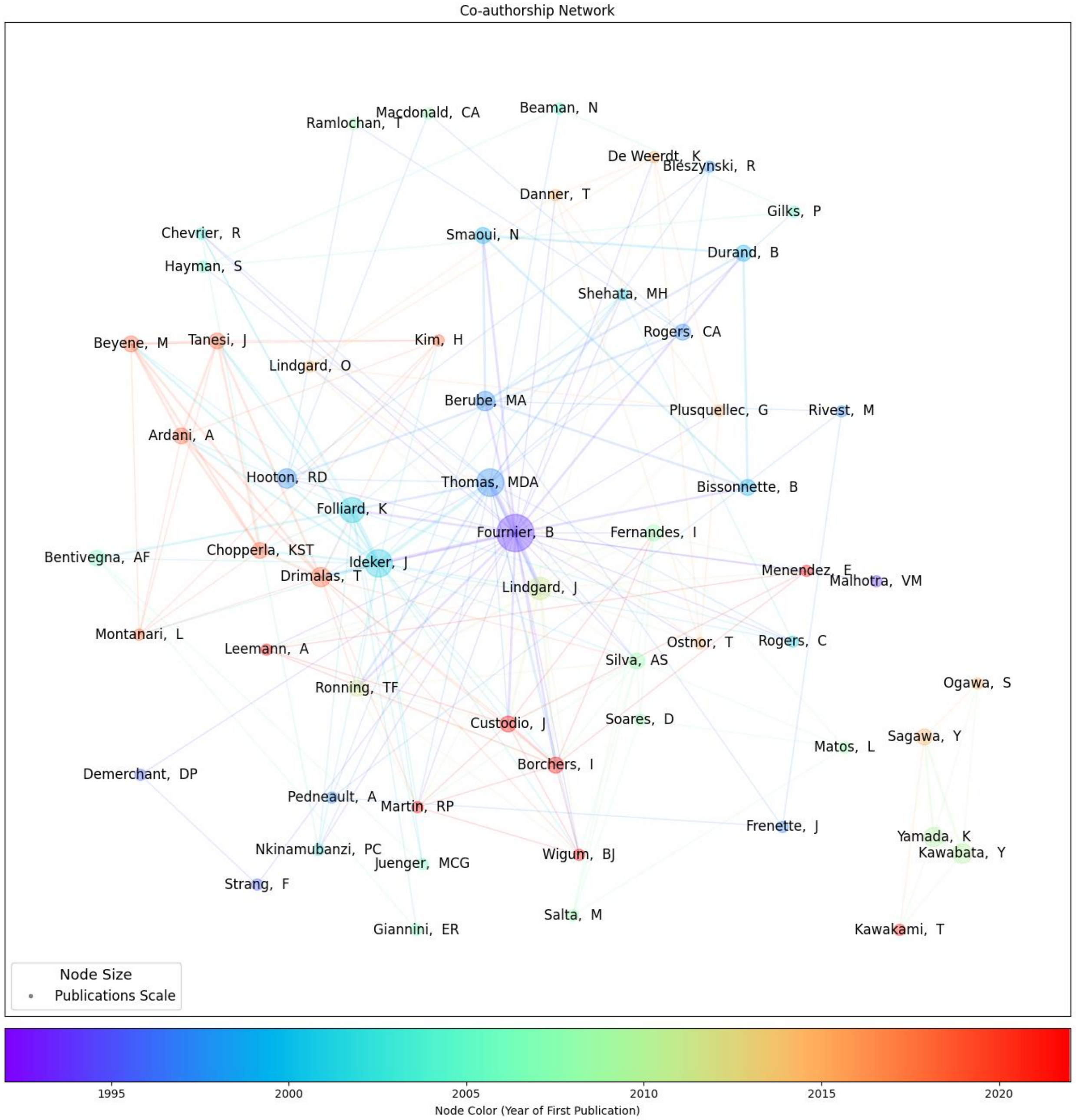
Ref: Fournier et. al. (2018)

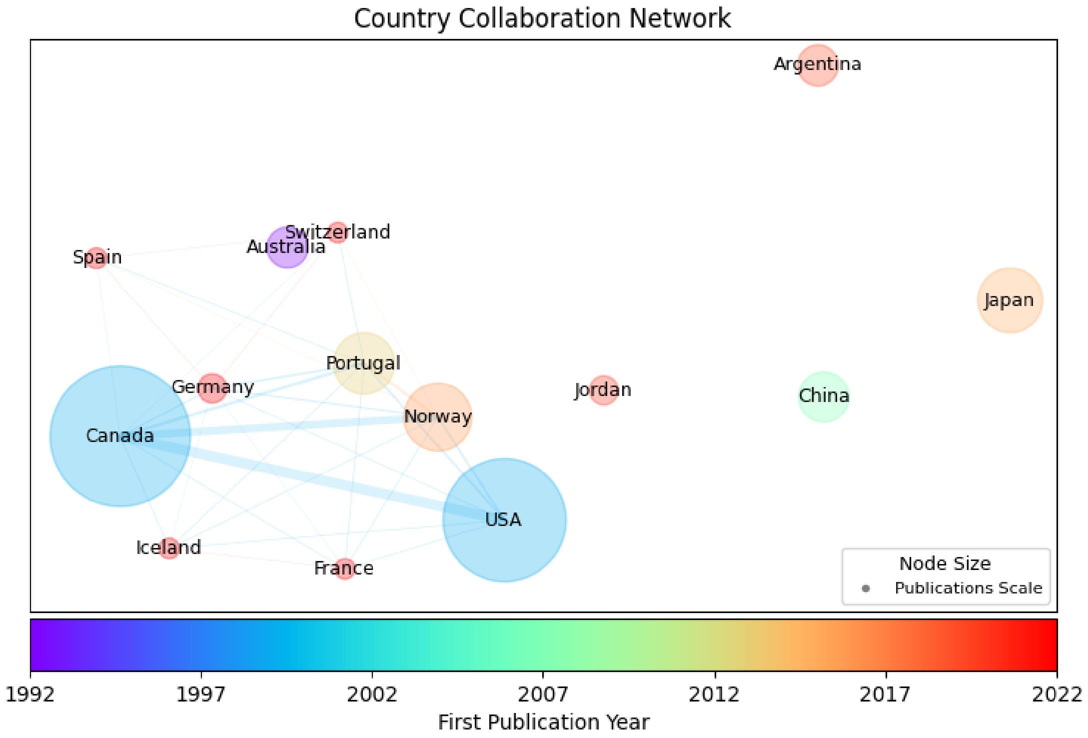
Preliminary Results: Evaluation procedures

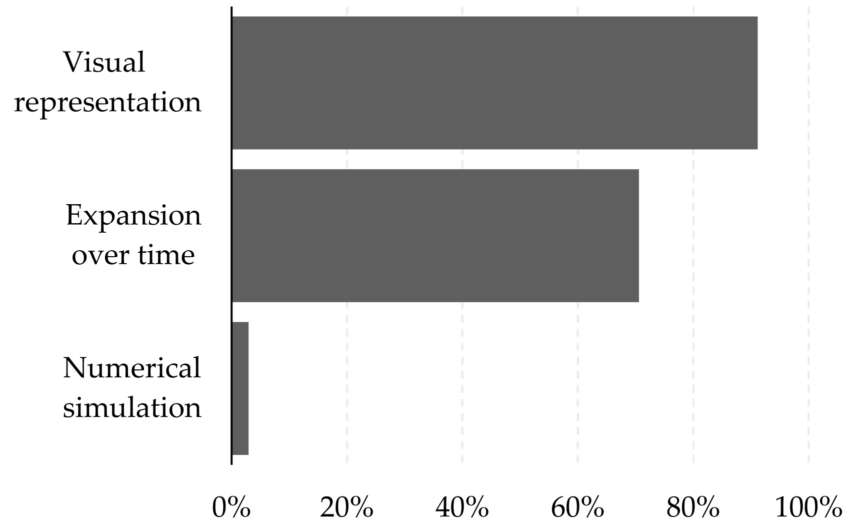
- measuring expansion/ length measurement (E)
- crack width (CW)
- porosity (P)
- compressive strength (CS)
- modulus of elasticity (ME)
- flexural strength (FS)
- chemical analysis (CA)
- pore solution analysis (PS)
- chloride diffusion (CD)
- rapid chloride permeability test (RCPT)
- alkali-leaching analysis (AL)
- salt scaling (SS)
- thermogravimetric analysis (TGA)
- concrete air-void spacing factor (ASF)
- Raman microscopy (RM)
- scanning electron microscope (SEM
- petrographic analysis (PA)
- damage rate index (DRI)
- stiffness damage test (SDT)
- qualitative damage assessment (QDA)
- ultrasonic pulse velocity (UPV)
- bulk electrical resistivity (BER)

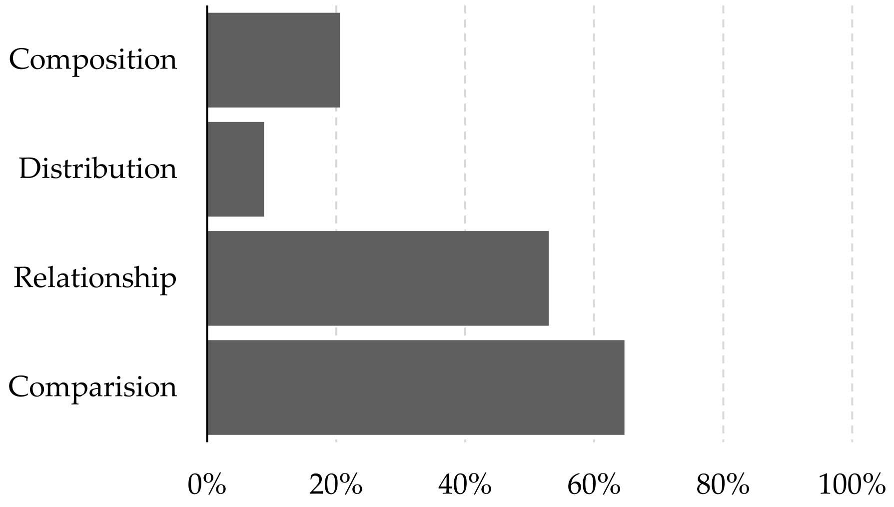
More than 20 procedures

Preliminary Results: Bibliometric Analysis





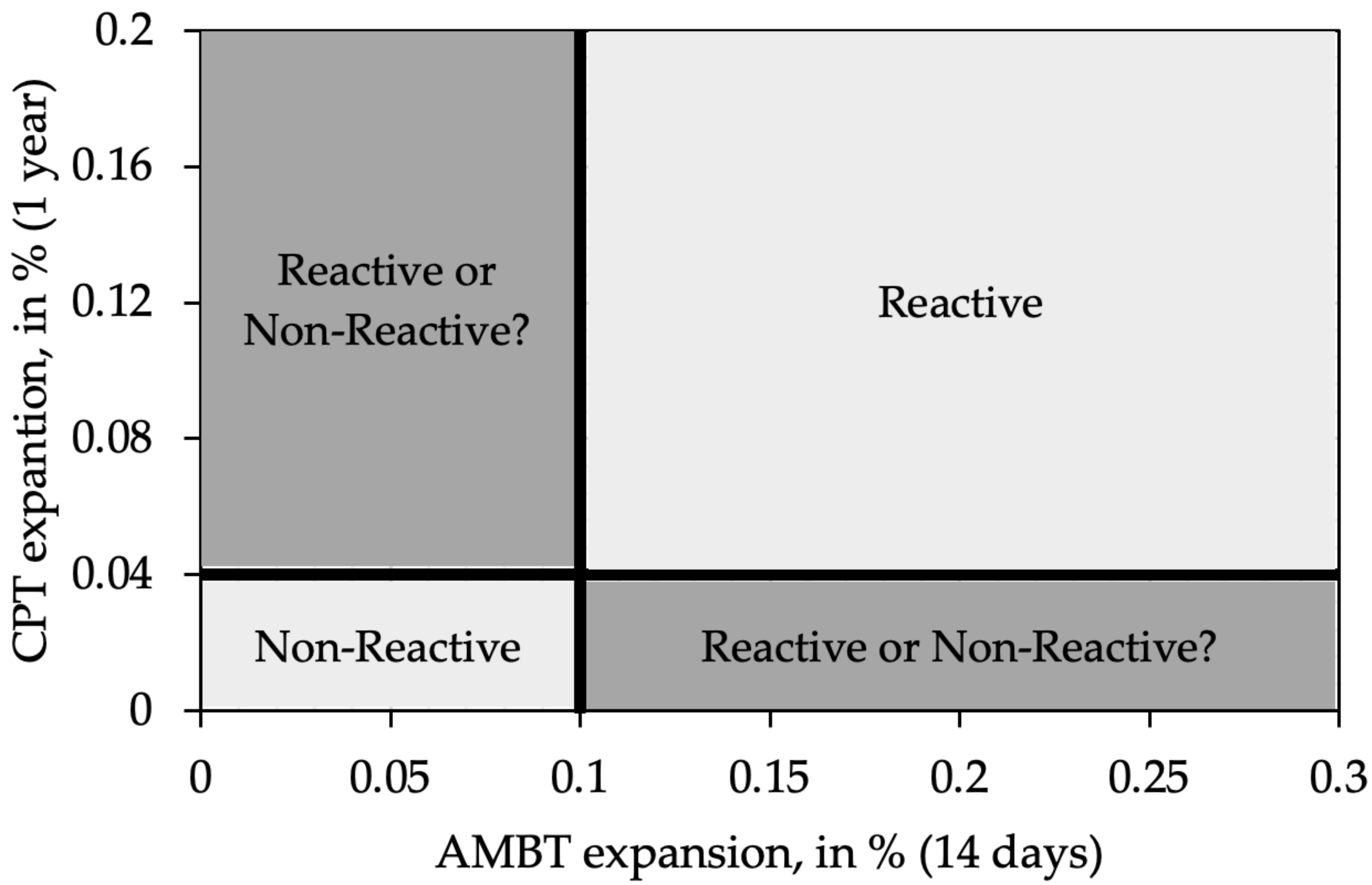




Laboratory methodologies

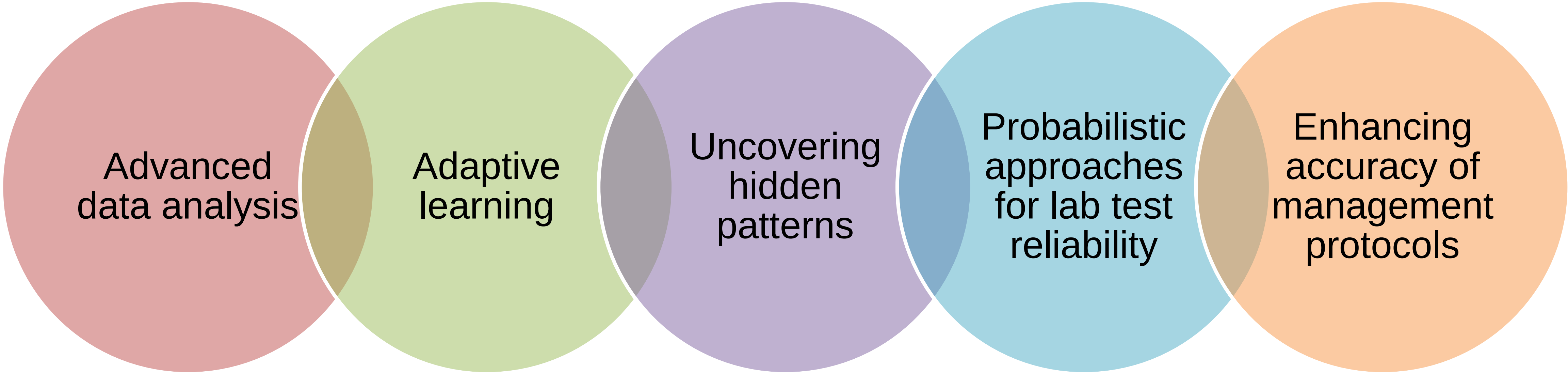
	CPT	ACPT	AW-CPT	NCPT	AMBT	MCPT	CCT
CPT	2	-	-	-	-	-	-
ACPT	3	0	-	-	-	-	-
AW-CPT	2	1	0	-	-	-	-
NCPT	1	1	0	0	-	-	-
AMBT	6	2	0	1	3	-	-
MCPT	1	1	0	0	0	0	-
CCT	0	1	0	0	0	1	0

Current Challenges



Discrepancies in the outcomes - Lack of clear thresholds for aggregate reactivity potential

ML to be incorporated in the solution



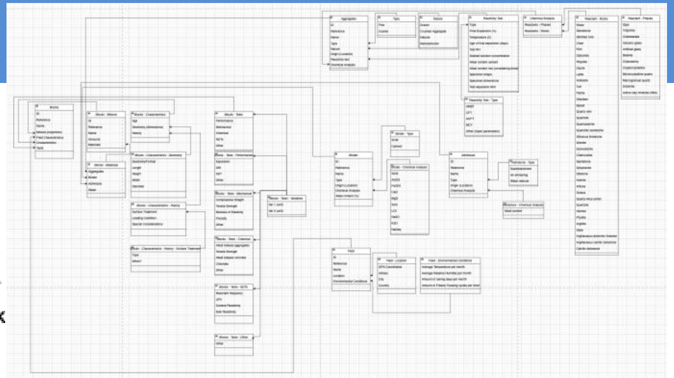
Action plan

Data Collection

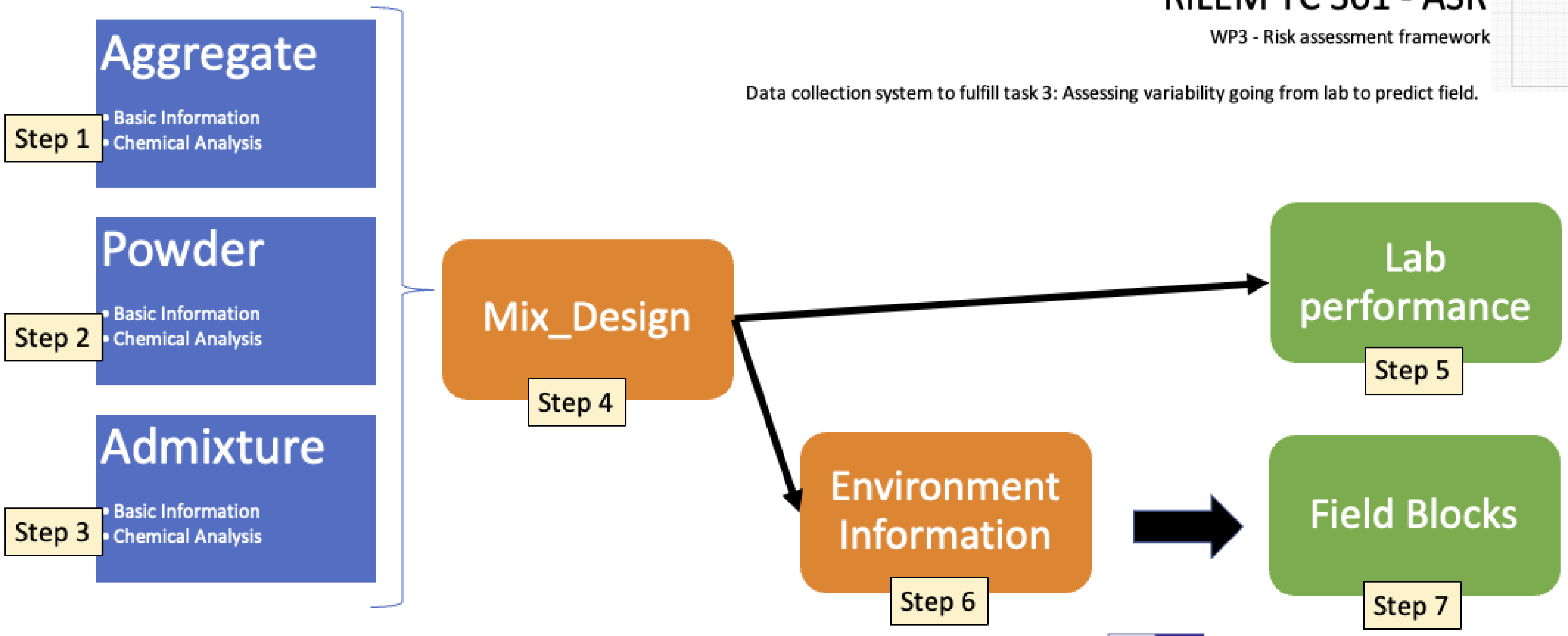
RILEM TC 301 - ASR

WP3 - Risk assessment framework

Data collection system to fulfill task 3: Assessing variability going from lab to predict field.



Validated data structure



legend

Orange cells: Drop list, you may select from a established list

Purple cells: Established/standardized parameters, you may change them according to your setup

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Data Cleaning

- Not standardized data collection process
- Changes in technology over the years
- Missing data

Data Exploration

- Descriptive analysis

(histogram, scatter plot, correlation)

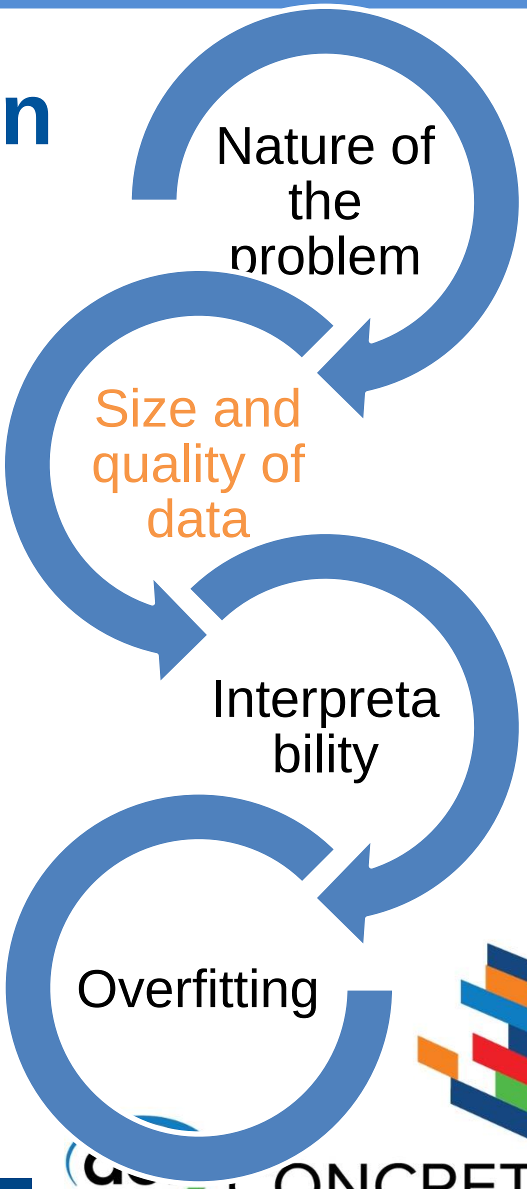
Feature Engineering

- Feature selection
- Feature creation/aggregation

ML to be incorporated in the solution

Prediction purposes

- Random forest: feature importance
- Support vector machines (SVMs): effective for a lot of variables from lab tests.
- Neural networks: deep learning for complex data structures and relationships
- K-Nearest neighbors (KNN): similar lab results and use them to predict field outcomes
- Decision tree: decision making by cut-offs or criteria from lab data



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Thanks

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