

PCE WITH WELL-DEFINED STRUCTURES AS POWERFUL CONCRETE SUPERPLASTICIZERS FOR ALKALI-ACTIVATED BINDERS

2ND INTERNATIONAL CONFERENCE ON POLYCARBOXYLATE SUPERPLASTICIZERS
28. SEPTEMBER 2017

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BUILDING TRUST

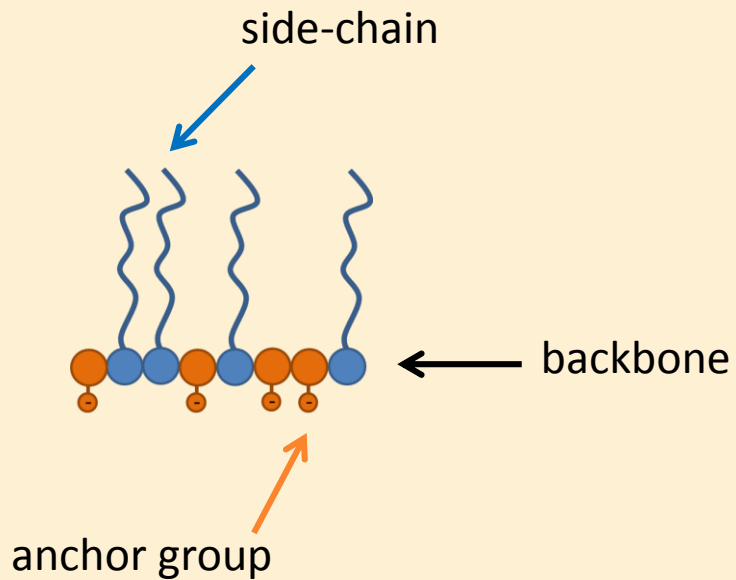


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INTRODUCTION

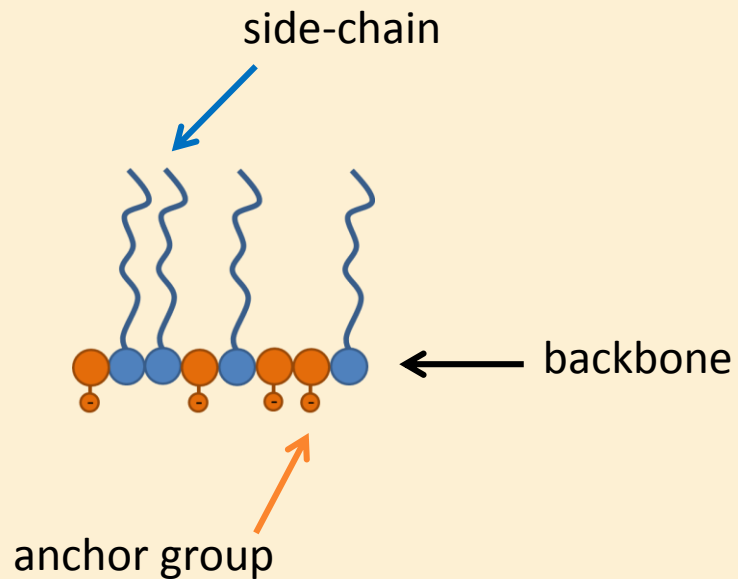
STRUCTURE



- random distribution of anchor group and side chains

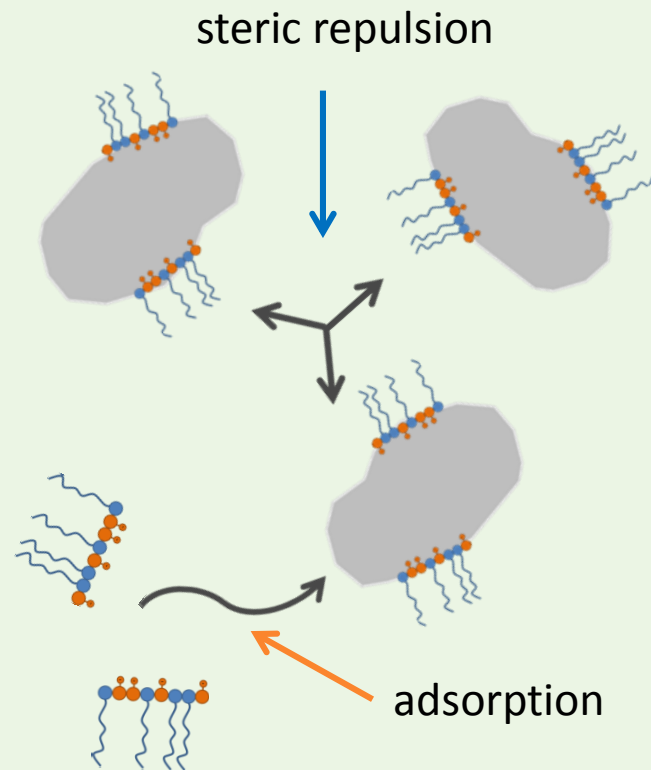
INTRODUCTION

STRUCTURE



- random distribution of anchor group and side chains

MECHANISM



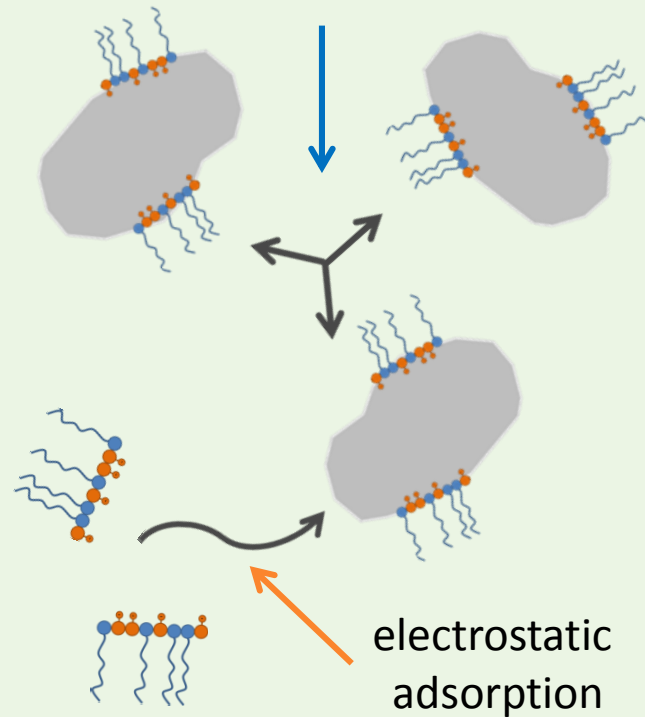
INTRODUCTION

WORKABILITY



MECHANISM

steric repulsion

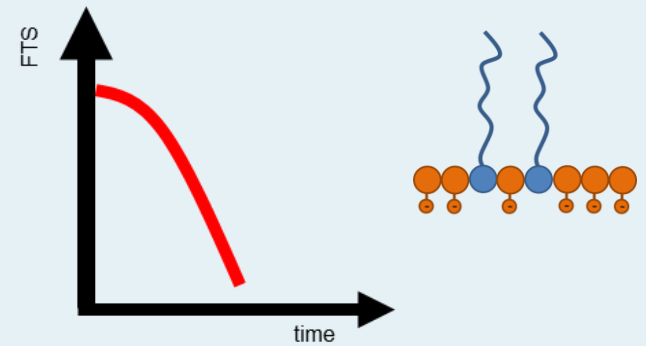
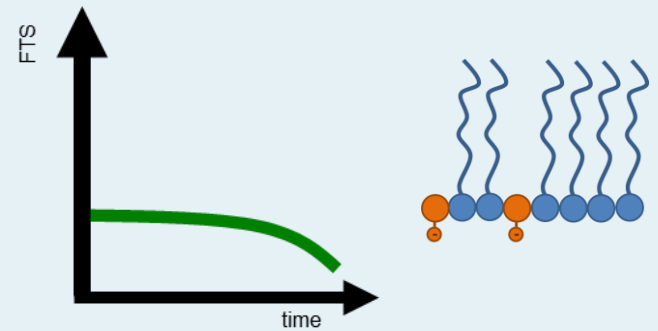


INTRODUCTION

WORKABILITY

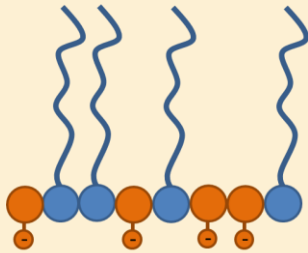


STRUCTURE-PROPERTY RELATIONSHIP



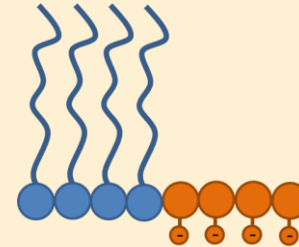
INTRODUCTION

EXISTING PCE



- **Comb polymer**
- Random distribution
- Defined by ratio between side chain and anchor groups

WELL-DEFINED PCE



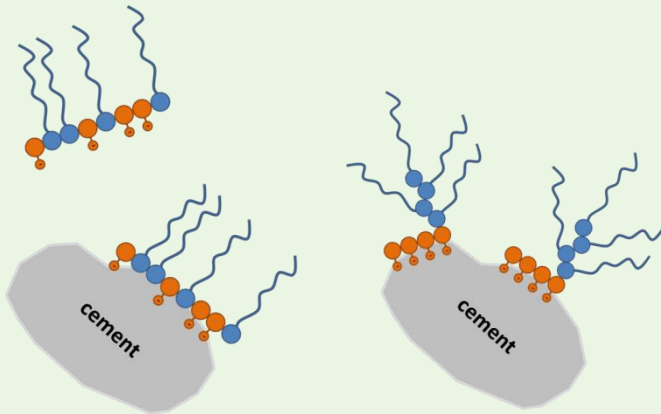
- **Brush structure**
- AB-block-structure
- Separated functionalities
- Defined by lengths of the blocks
- High local anionic charge density

INTRODUCTION

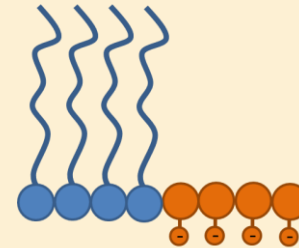
- very strong adsorptive capability
- unique mortar and concrete performance

random PCE

well-defined PCE

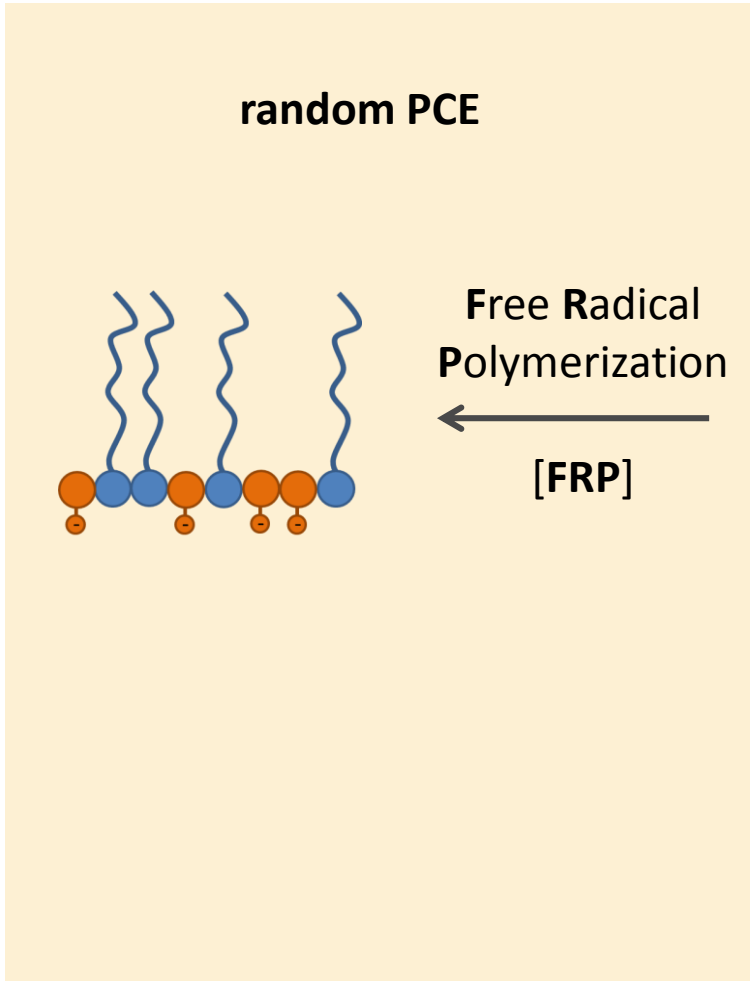


WELL-DEFINED PCE



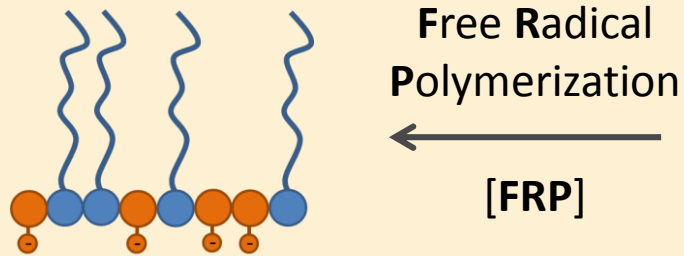
- **Brush structure**
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POLYMER SYNTHESIS

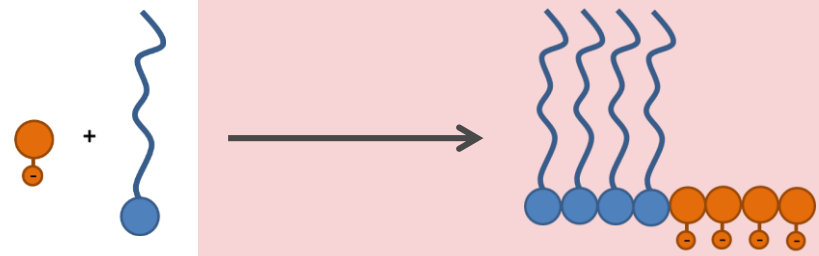


POLYMER SYNTHESIS

random PCE



well-defined PCE



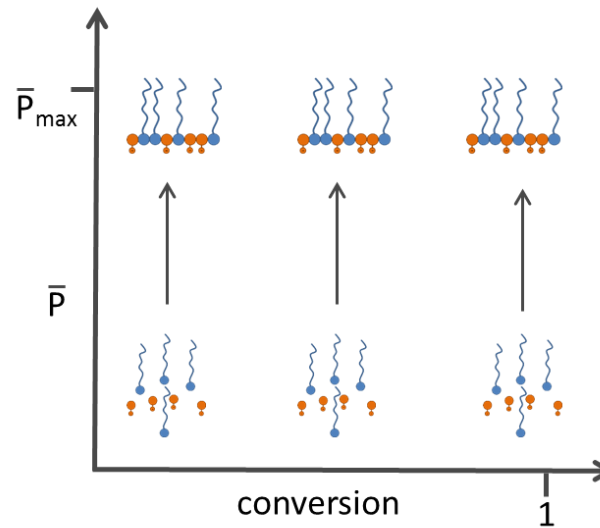
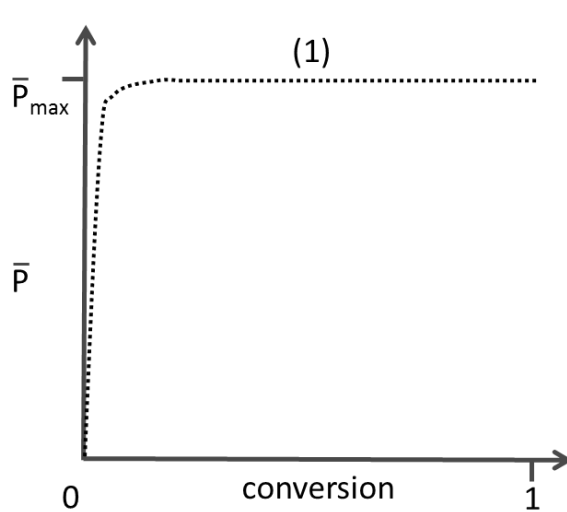
- not accessible with existing FRP technology

POLYMER SYNTHESIS

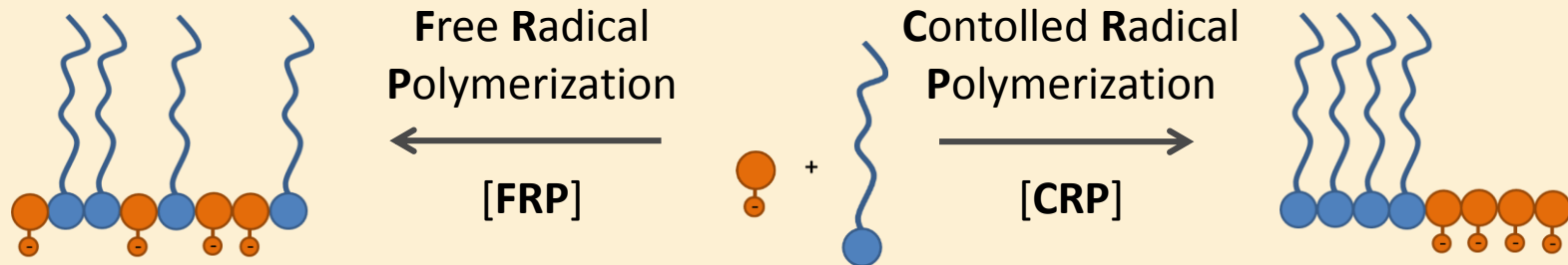
FRP:

- Initiation
- Propagation
- Termination

«fast» reaction
final polymers are built immediately
new chains start continuously



POLYMER SYNTHESIS



Controlled Radical Polymerization Types

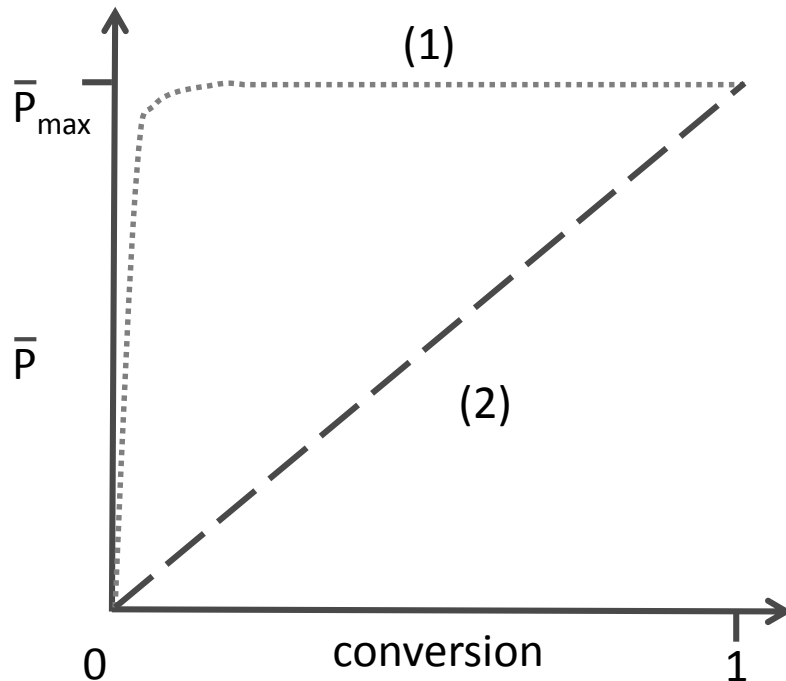
- NMP: Nitroxide-mediated polymerization
- ATRP: Atom transfer radical polymerization
- RAFT: Reversible addition-fragmentation chain transfer polymerization

POLYMER SYNTHESIS

CRP:

- Initiation
- Propagation
- Termination

«slow» reaction
final polymers are built over time
all chains start at the beginning



1. [FRP]: with terminating reaction

2. [CRP]: without terminating reaction

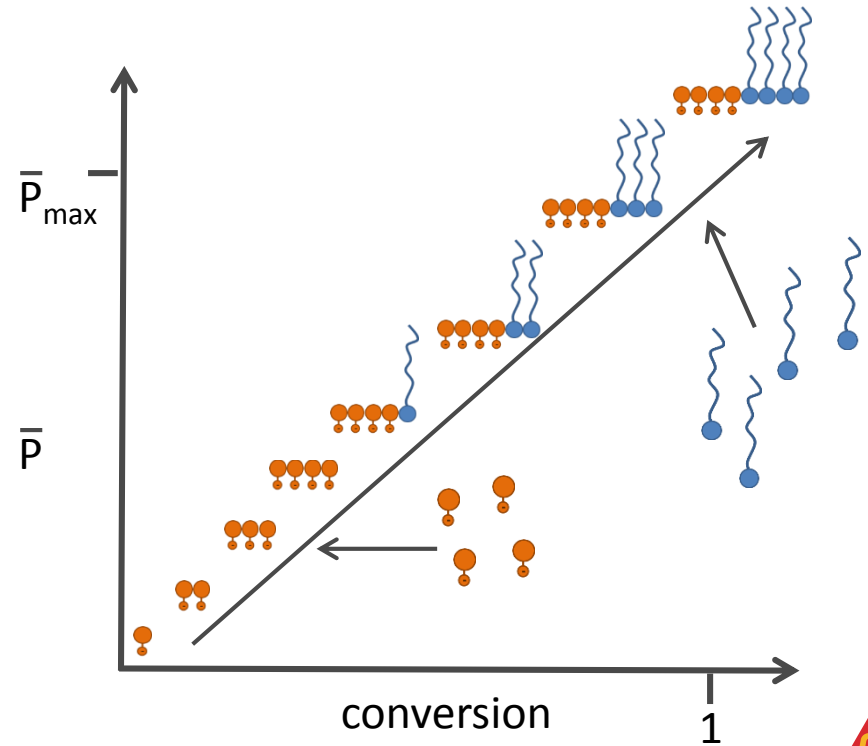
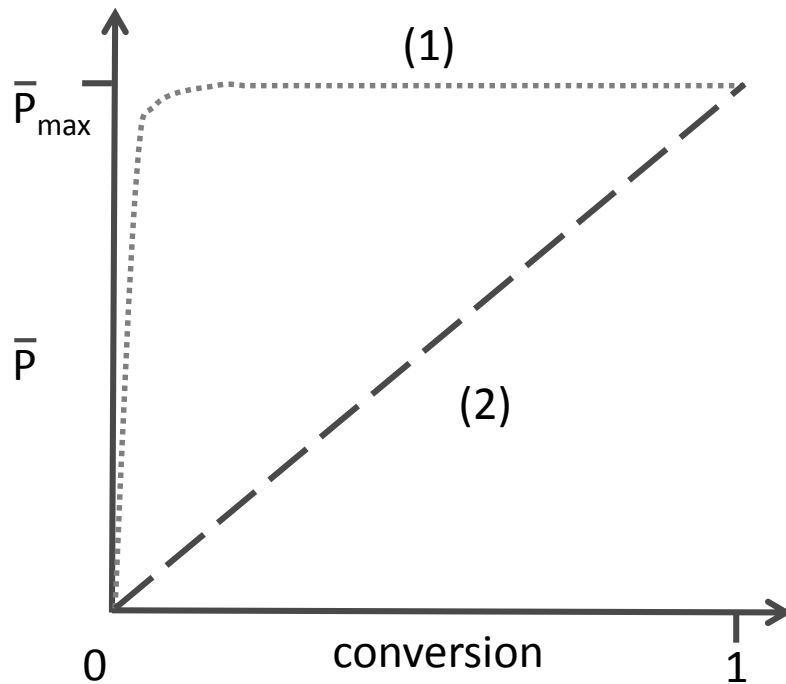
$$DP = \frac{[M]_0}{[R]_0} * \text{conversion}$$

POLYMER SYNTHESIS

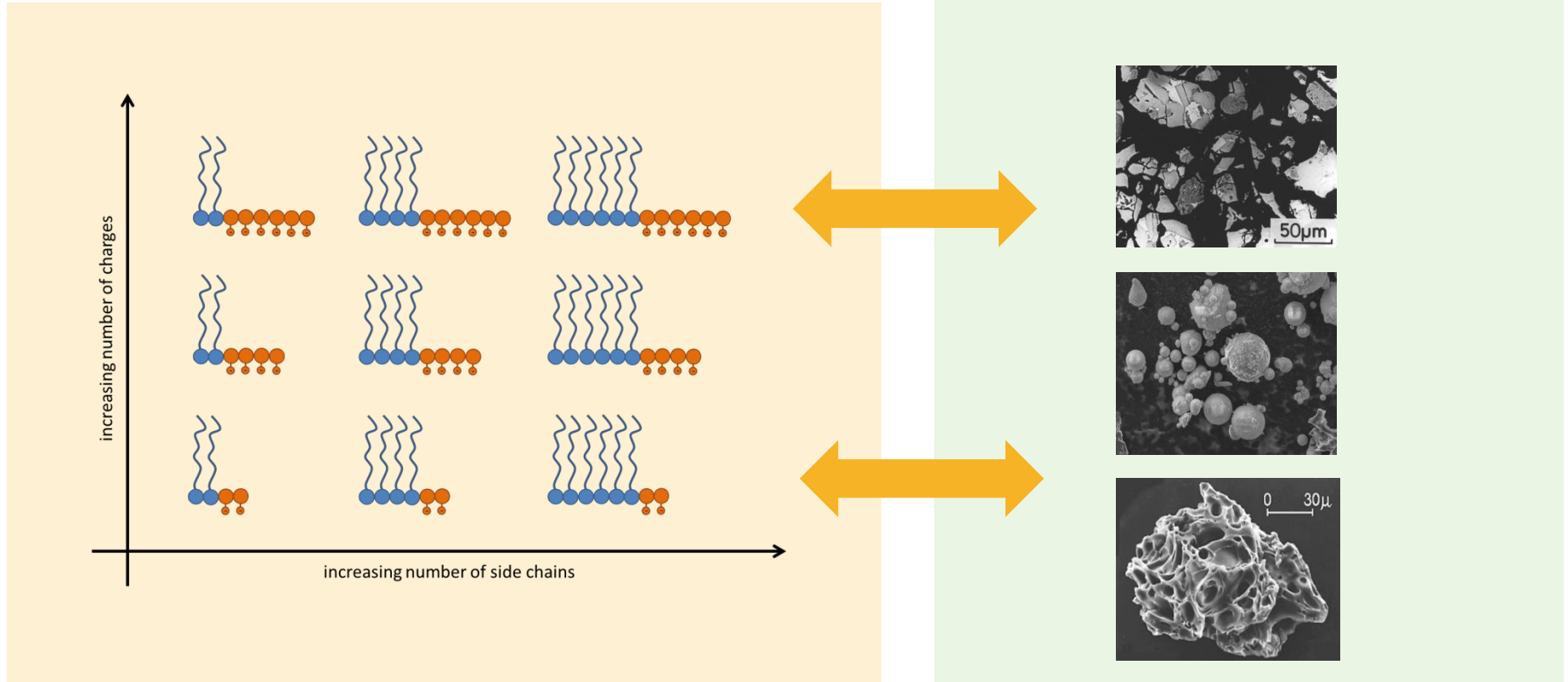
CRP:

- Initiation
- Propagation
- Termination

«slow» reaction
final polymers are built over time
all chains start at the beginning



POLYMER SYNTHESIS



- Design polymer architecture according the different needs

PCE IN ALKALI ACTIVATED BINDERS

■ DEFINITION

SCMs are materials that, when used in conjunction with OPC, contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity or both.



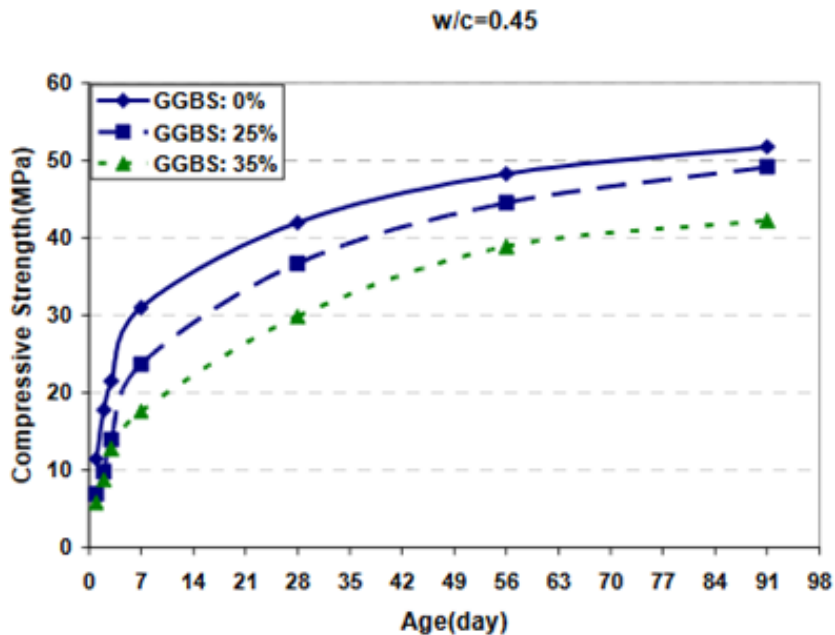
- Fly Ash (Class C)
- Metakaolin
- Silica fume
- Fly ash (Class F)
- Slag
- Calcined shale

PCE IN ALKALI ACTIVATED BINDERS

- SUSTAINABILITY
 - Reduces carbon dioxide production
 - Reduces energy consumption
 - Helps recycling some industrial byproducts
- APPLICATION BENEFITS
 - Generally reduces material costs
 - Improves strength of the hardened concrete
 - Improves durability of the hardened concrete
 - Reduce heat of hydration

PCE IN ALKALI ACTIVATED BINDERS

■ DRAWBACKS



- Slag leads to a decreased early strength development

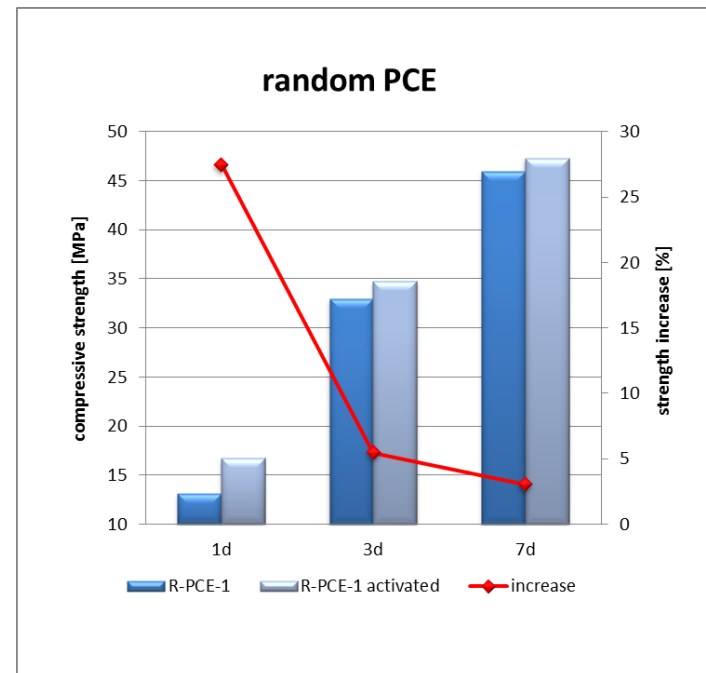
[2]: M. Nili, M. Tadayon, «The Relationships between Setting Time and Early Age Strength of Concrete containing Silica fume, Fla ash and Slag»

PCE IN ALKALI ACTIVATED BINDERS

mix-design (mortar)

cement Cem I 42.5N	525g
slag	225g
aggregates 0 – 8mm	3140g
w/c	0.44
PCE dosage relative to binder	0.8%
NaOH relative to slag	1.25%

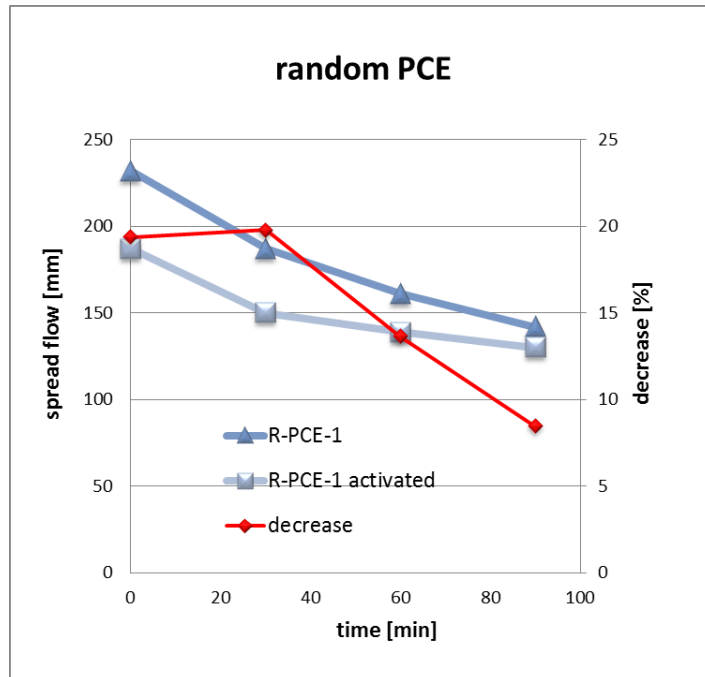
STRENGTH DEVELOPMENT



- NaOH activation leads to increased early strength

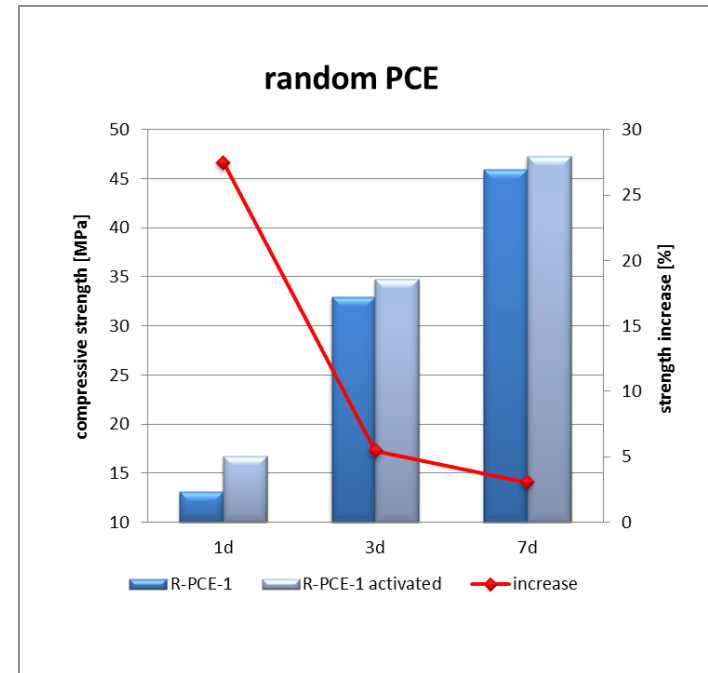
PCE IN ALKALI ACTIVATED BINDERS

FRESH MORTAR PROPERTIES



- random-PCE are not compatible with alkaline activation

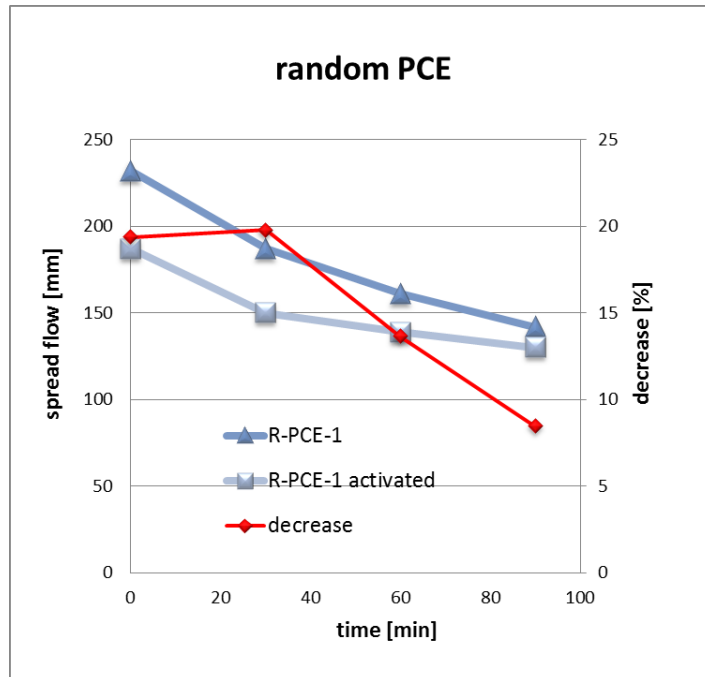
STRENGTH DEVELOPMENT



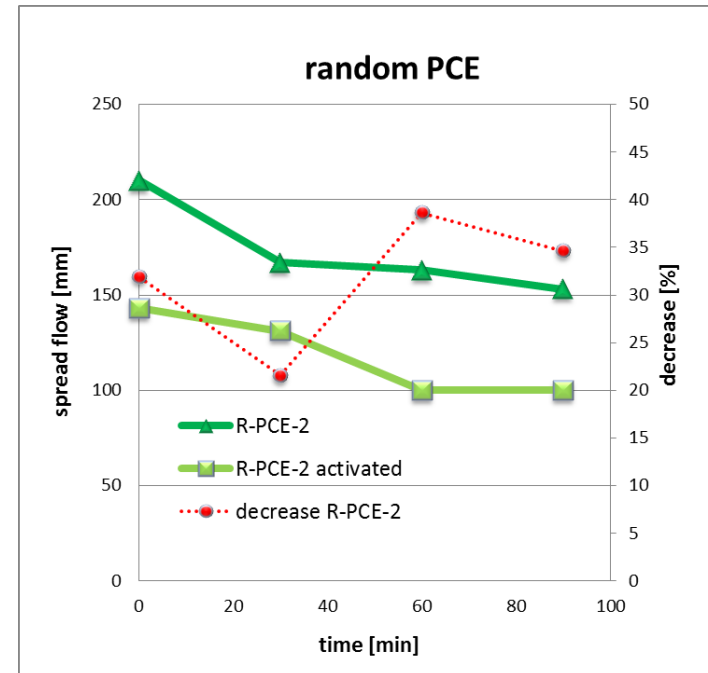
- NaOH activation leads to increased early strength

PCE IN ALKALI ACTIVATED BINDERS

R-PCE-1



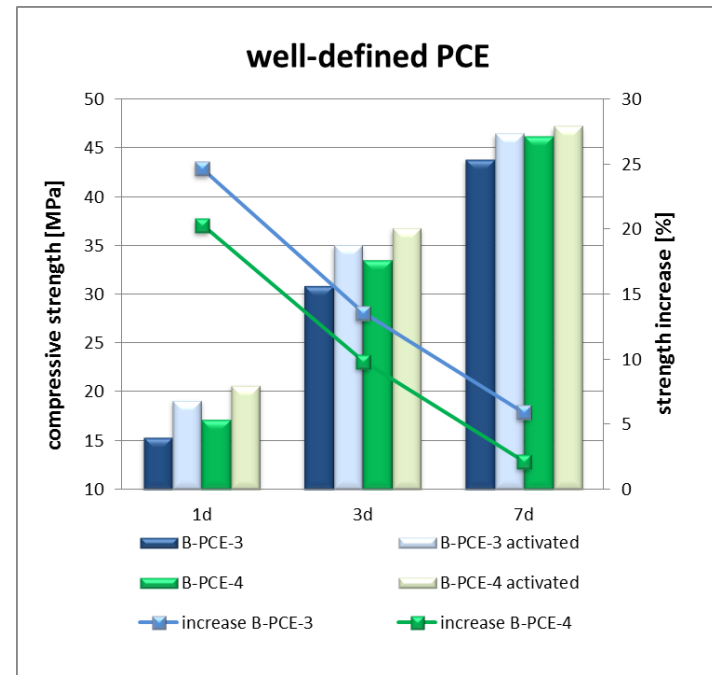
R-PCE-2



- random-PCE are not compatible with alkaline activation
- Depended on the structure the incompatibility is more significant

PCE IN ALKALI ACTIVATED BINDERS

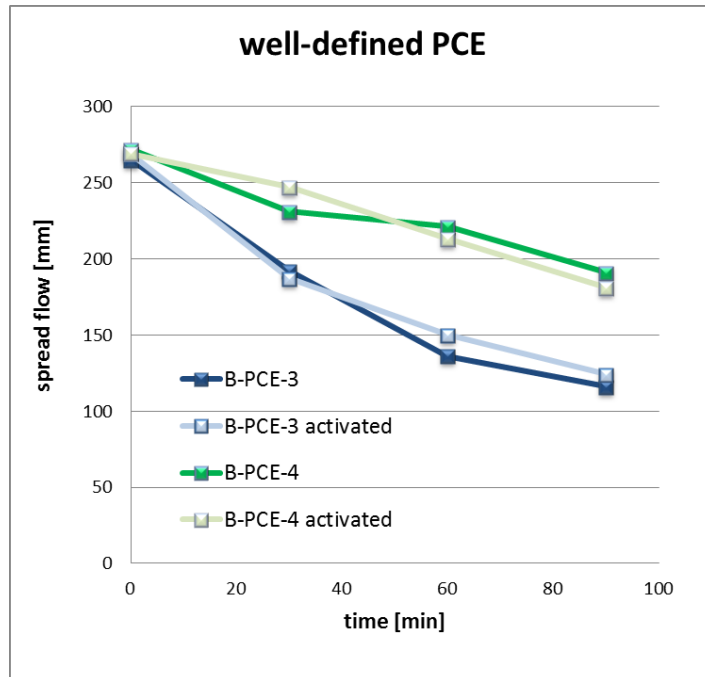
STRENGTH DEVELOPMENT



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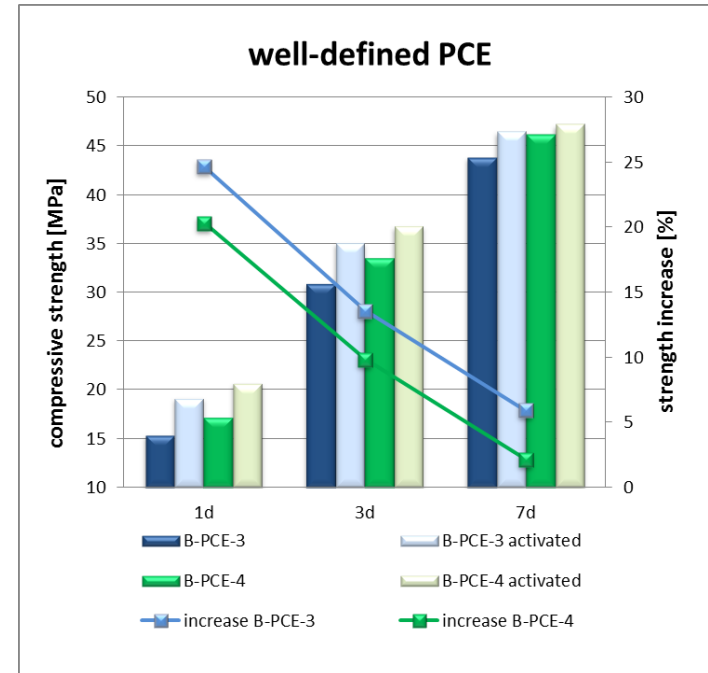
PCE IN ALKALI ACTIVATED BINDERS

FRESH MORTAR PROPERTIES



- block-PCE are compatible with alkaline activation

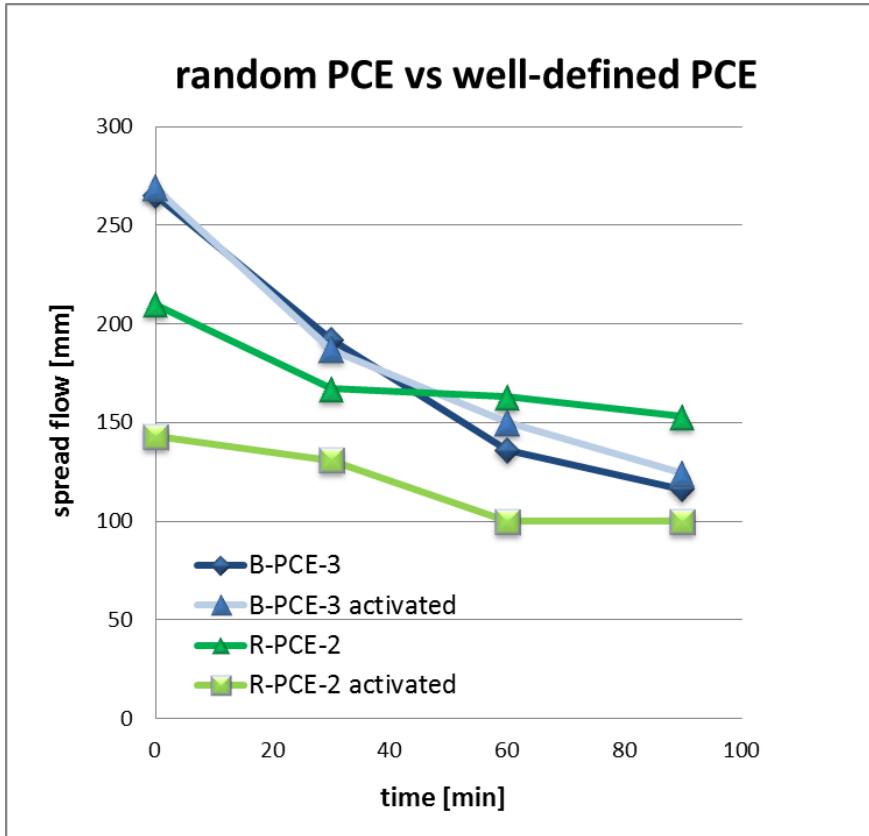
STRENGTH DEVELOPMENT



- NaOH activation leads to increased early strength

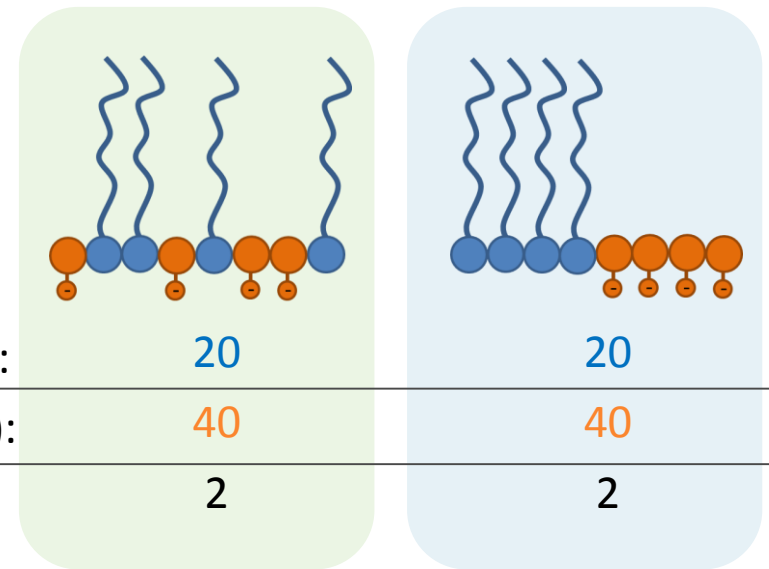
PCE IN ALKALI ACTIVATED BINDERS

FRESH MORTAR PROPERTIES



random-PCE

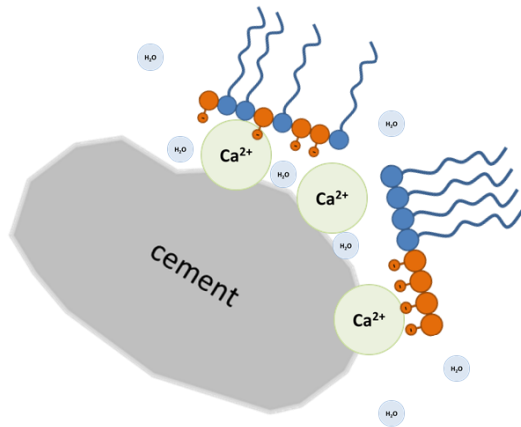
block-PCE



- Same composition but different structure

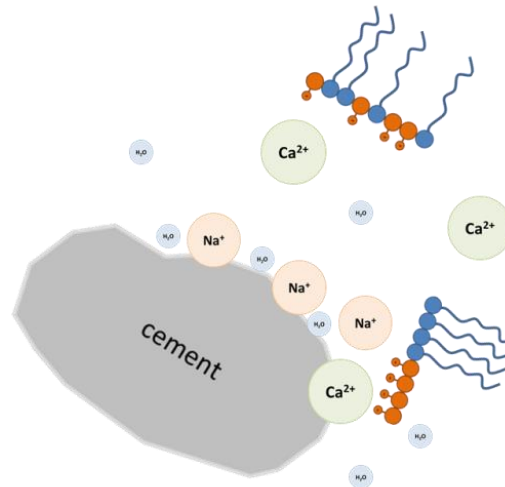
PCE IN ALKALI ACTIVATED BINDERS

non-activated system

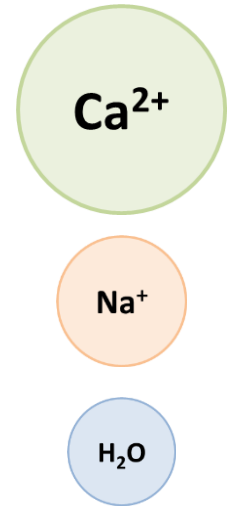


- PCE adsorption in presence of cement released calcium

alkaline-activated system



- Random-PCE: insufficient adsorption in the presence of sodium
- Block-PCE: structures are able to adsorb even on unattractive particle surface



SUMMARY

Structure

- Block PCE can only be synthesized by a controlled free radical polymerization (CRP).
- Block Polymers enable a very strong adsorptive behavior compared to random PCE polymers.
- The structures of these polymers can easily designed according the needs

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Structure

- Block PCE can only be synthesized by a controlled free radical polymerization (CRP).
- Block Polymers enable a very strong adsorptive behavior compared to random PCE polymers.
- The structures of these polymers can easily be designed according to the needs

Application

- Well-defined polymers are compatible with alkali-activated binders in contrast to existing random-structured PCE.
- Early strength development can be enhanced by adding alkaline without losing fresh concrete properties when well-defined polymers are used.

THANK YOU FOR YOUR ATTENTION