Institut für Baustoffe

Leibniz Universität Hannover

Research at the

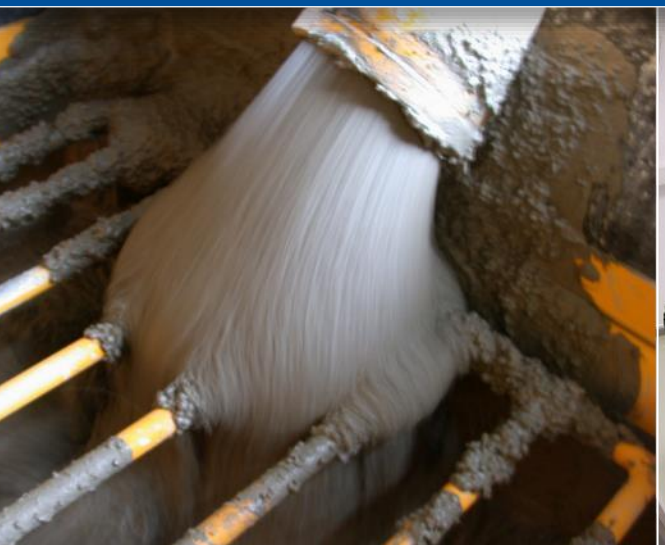
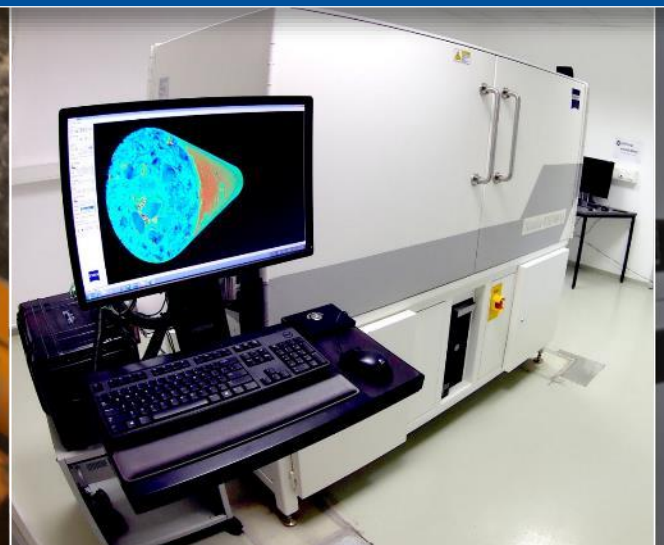
Institute for Building Materials

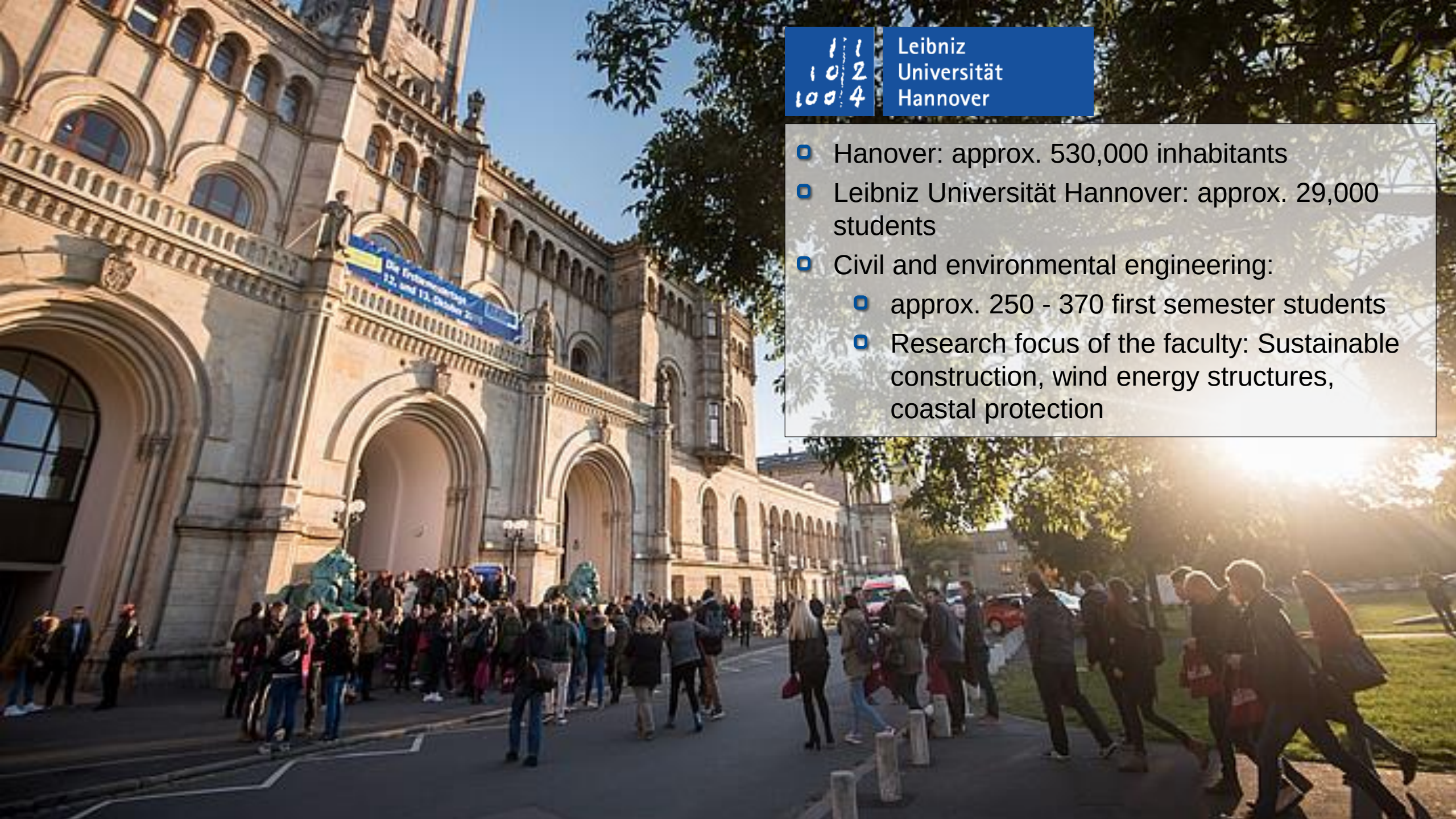
Leibniz University Hannover

Prof. Dr.-Ing. Michael Haist and M.Sc. Bastian Strybny

Meeting with Delegation from Mykolajiw, Ukraine

Hannover, Dec. 3, 2024



Leibniz Universität Hannover

- Hanover: approx. 530,000 inhabitants
- Leibniz Universität Hannover: approx. 29,000 students
- Civil and environmental engineering:
  - approx. 250 - 370 first semester students
  - Research focus of the faculty: Sustainable construction, wind energy structures, coastal protection

Faculty of Civil Engineering and Geodesy

Structural engineering

Water and the environment

Geodesy and geoinformatics

18 Institutes
26 professors
421 employees

2221 students
32 % female students
28 % International students

Photos: FBG/ C. Bierwagen

Institutes and other facilities

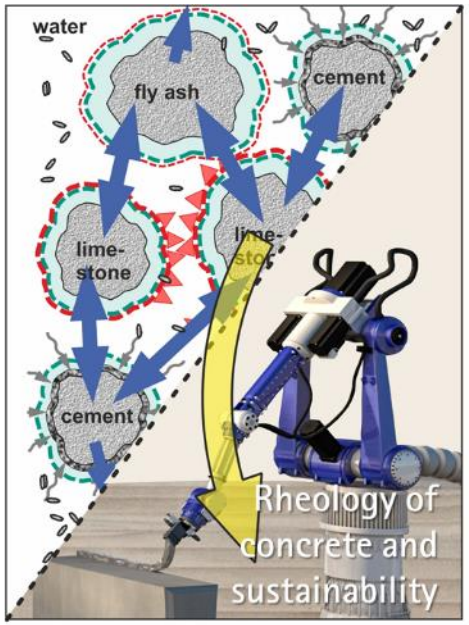
Structural engineering	Water and environment	Geodesy and geoinformatics
▪ Institute for Construction Management and Digital Building ▪ Institute of Mechanics of Structures and Computational Mechanics ▪ Institute for Building Physics ▪ Institute for Building Materials ▪ Institute for Solid Construction ▪ Institute for Risk and Reliability ▪ Institute for Steel Construction ▪ Institute for Statics and Dynamics ▪ Institute for Wind Energy Systems	▪ Ludwig-Franzius-Institute for Hydraulic, Estuarine and Coastal Engineering ▪ Institute for Geotechnics ▪ Institute for Urban Water Management and Waste Technology ▪ Institute of Fluid Mechanics and Environmental Physics in Civil Engineering ▪ Institute for Hydrology and Water Management	▪ Geodetic Institute ▪ Institute for Earth Measurement ▪ Institute of Cartography and Geoinformatics ▪ Institute for Photogrammetry and GeoInformation

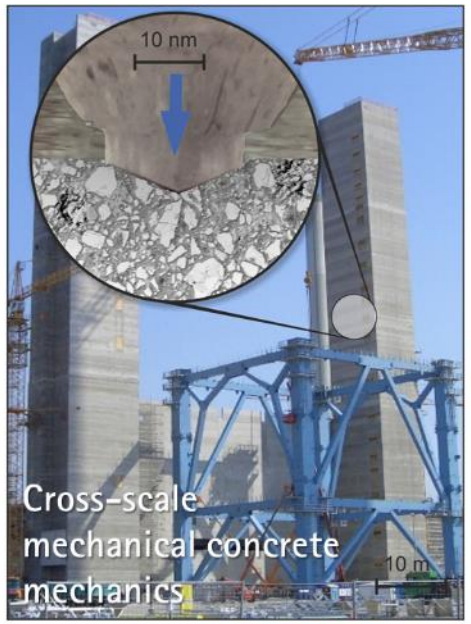
Further facilities

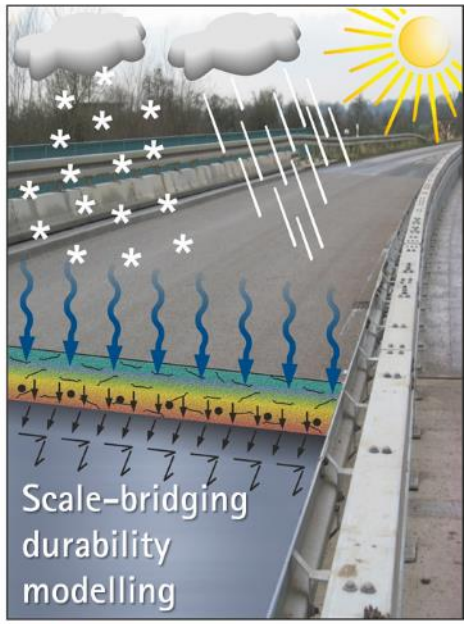
- Test center load-bearing structures (collegial management)
- Hanover Materials Testing Institute for the Building Industry (part of the Lower Saxony Ministry of Economics)
- Working Group for Continuing Education in Civil Engineering - Structural Engineering
- Working Group for Continuing Education in Civil Engineering - Distance Learning Water and Environment

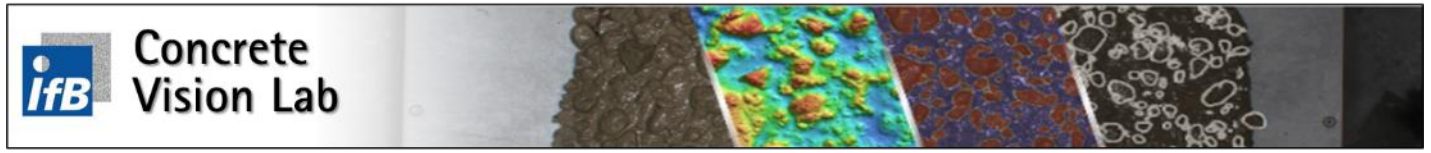
Institute for Building Materials Science

Research









MPA Hannover: Materials testing institute of the state of Lower Saxony

Official testing lab for the state of Lower Saxony

- Product testing and certification
- Producer accredition and notification

Wind Energy Test Center

What we stand for - key areas of work at the IfB

Frost and acid resistance

RC cements and concretes

Functionalized concrete

Sensors

Self-learning concrete production

Sustainable and durable construction

Concrete 4.0

Computer Vision

Neural networks

Clinker efficiency Eco-concrete

Sustainability assessment

Mechanisms of flow

Special concretes

Pumps

Fresh concrete Rheology

Venting

Homogeneity

Compaction

Fair-faced concrete

Creep

Shrinkage

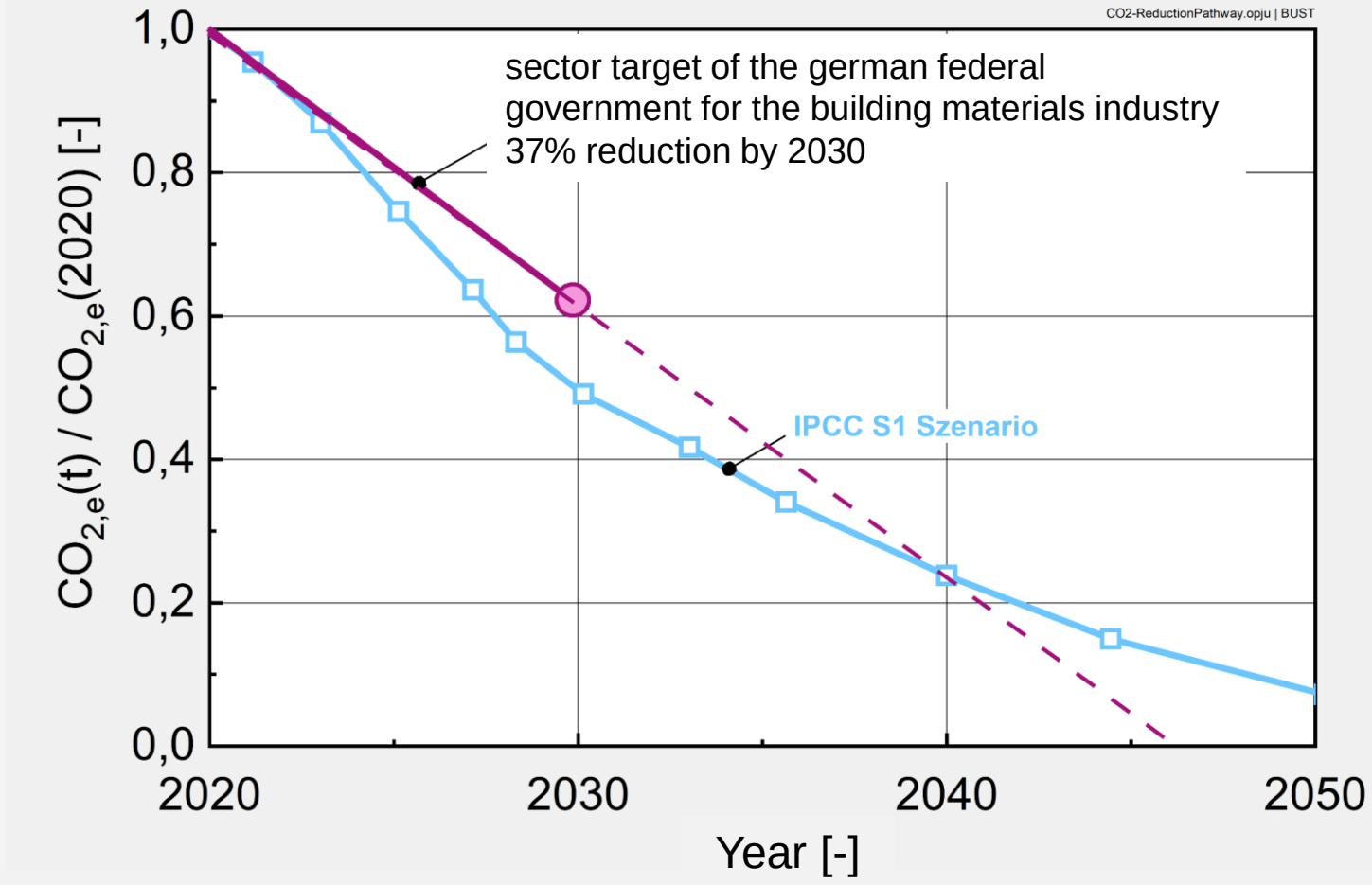
Long-term deformation and fatigue

Fatigue

Cyclical influences

Sustainable Concrete: Goals

Reduction Pathway



$CO_{2,e}$ = equivalent CO_2 emissions = measure of global warming (**Global Warming Potential, GWP**)

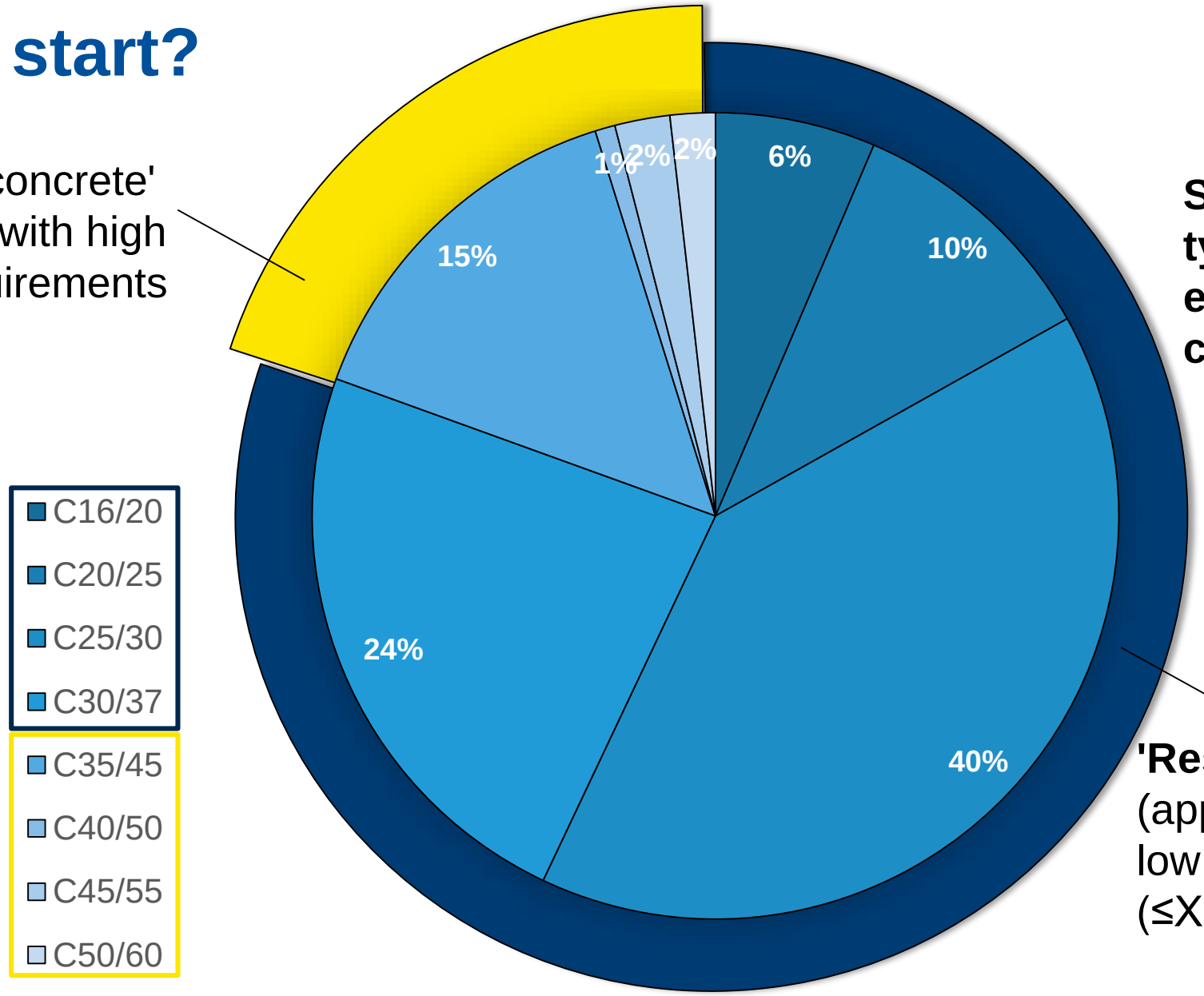
Ecological Solution (e.g. 2030)

$$\frac{\left[\frac{\Sigma GWP}{\text{Functional Unit}}\right]_{Eco}}{\left[\frac{\Sigma GWP}{\text{Functional Unit}}\right]_{Ref}} \leq \text{Limit state } \alpha_{GWP}$$

Reference Solution (2020)

Where to start?

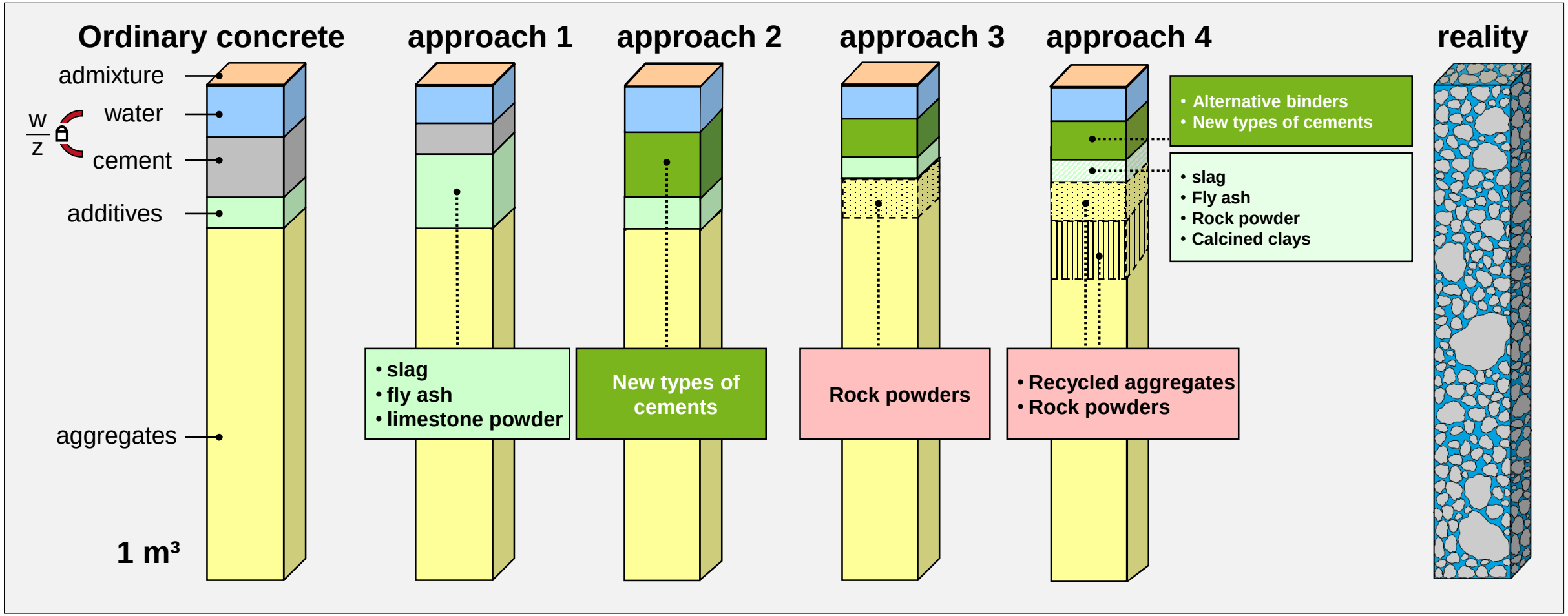
'Engineering concrete' approx. 20 % with high durability requirements



Share of concrete types in CO_2 emissions (ready-mix concrete)

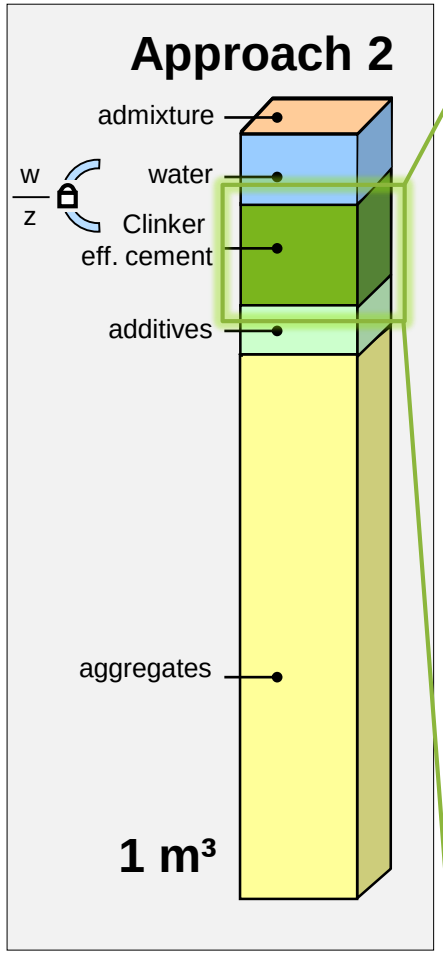
'Residential concrete' (approx. 80 %) with only low durability requirements (≤XC4, ≤XF2, ≤XA1)

Pathways to Low Carbon Concrete



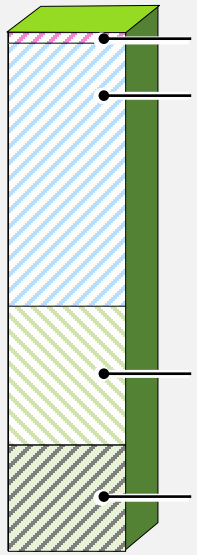
How feasible are the individual approaches?

Approach 2: New Clinker Efficient Cements



Clinker efficient cements: New technological approach

Increasing efficiency by mixing of several cement replacement substances



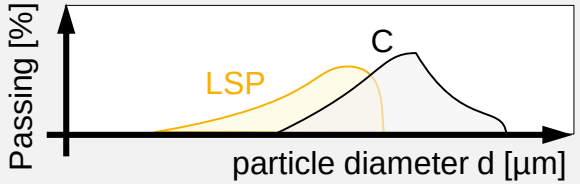
Sulfate carrier

Limestone powder LSP

Slag S or Calcined Clay CC

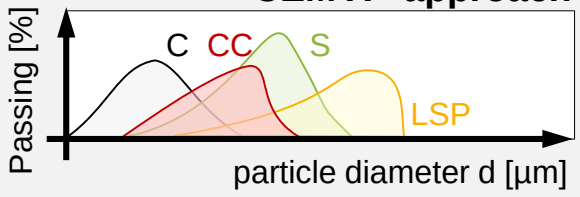
Ordinary Portland clinker C

Composite cements today

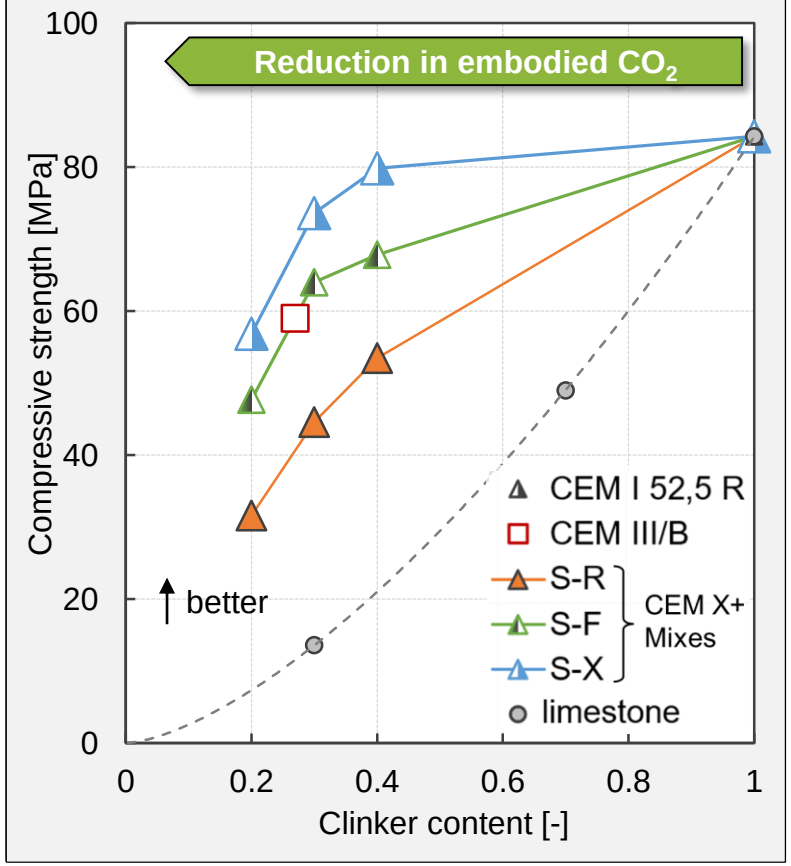


- Multi-Component mix
- Reduced content of reactive constituents
- Adapt granulometry to reactivity

CEM X+ approach



Strength of CEM X+ mixes



Schack, Tobias and Haist, Michael, Performance Assessment of Eco-Efficient Concrete with Ternary Blended Cementitious Materials Considering the Effect of Binder Component Fineness. Available at SSRN: https://ssrn.com/abstract=4696547 or http://dx.doi.org/10.2139/ssrn.4696547.

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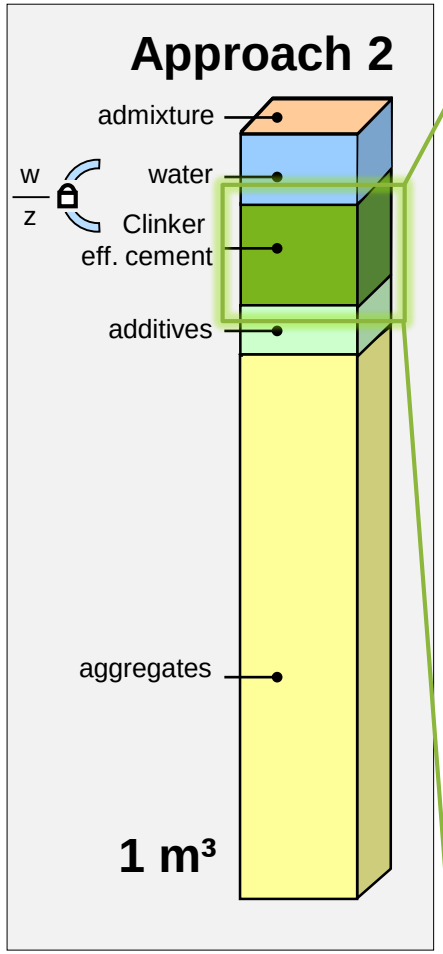

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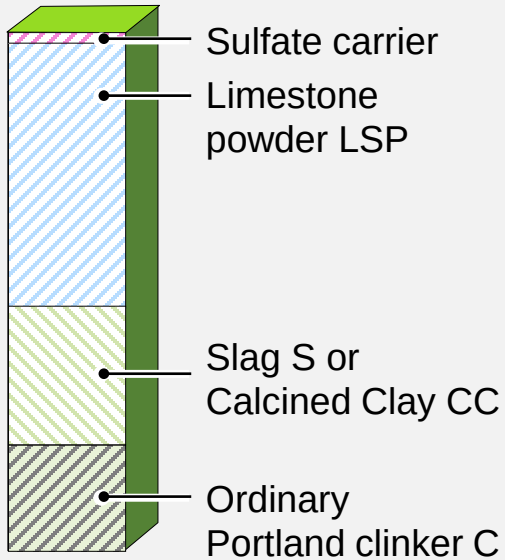
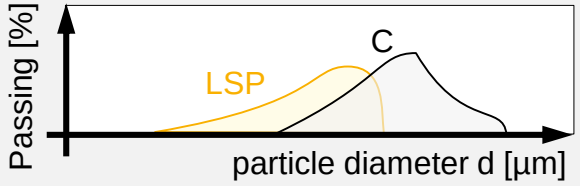


Composite cements today



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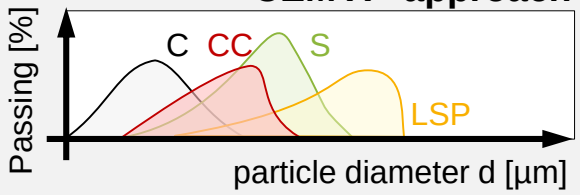
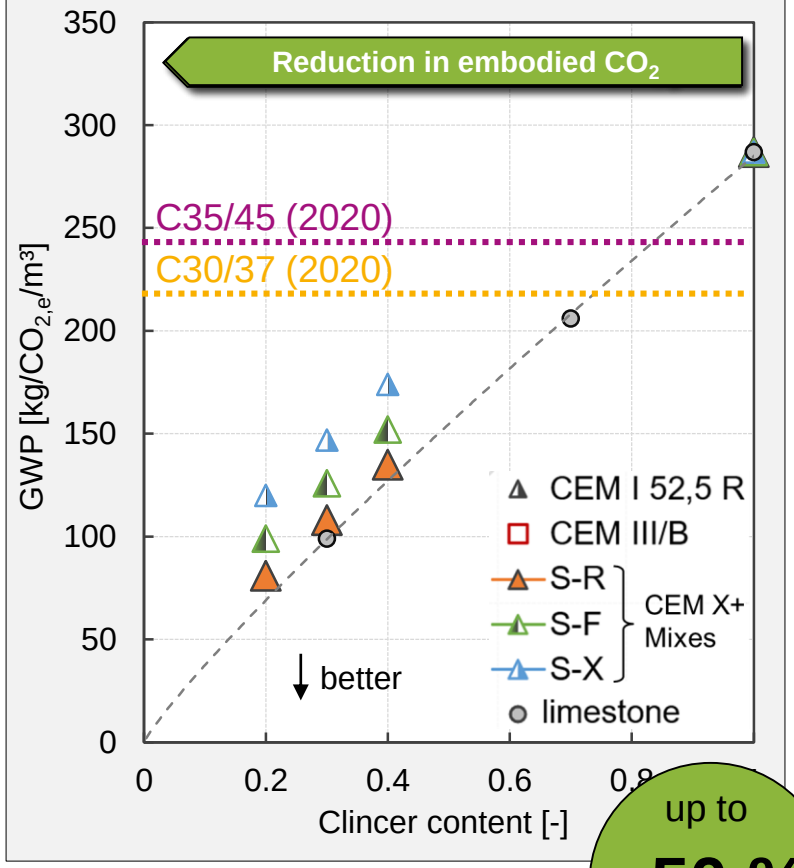


CO_2-Emissions of CEM X+ mixes

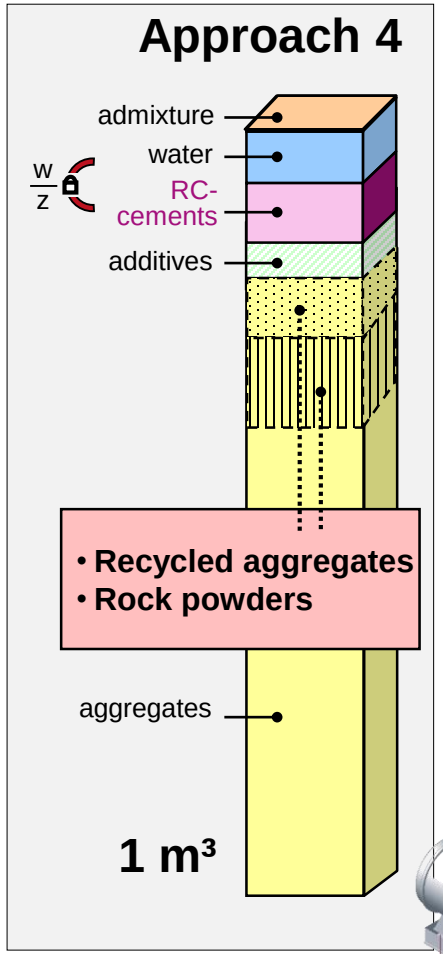


up to **- 50 %** CO_2

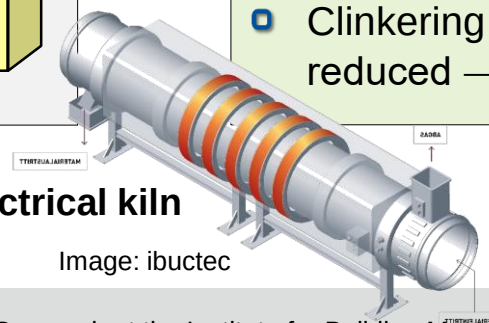
Substantial CO_2 reduction possible today! But reduced Workability

Schack, Tobias and Haist, Michael, Performance Assessment of Eco-Efficient Concrete with Ternary Blended Cementitious Materials Considering the Effect of Binder Component Fineness. Available at SSRN: https://ssrn.com/abstract=4696547 or http://dx.doi.org/10.2139/ssrn.4696547.

Approach 4: CO_2-neutral Recycling Cement

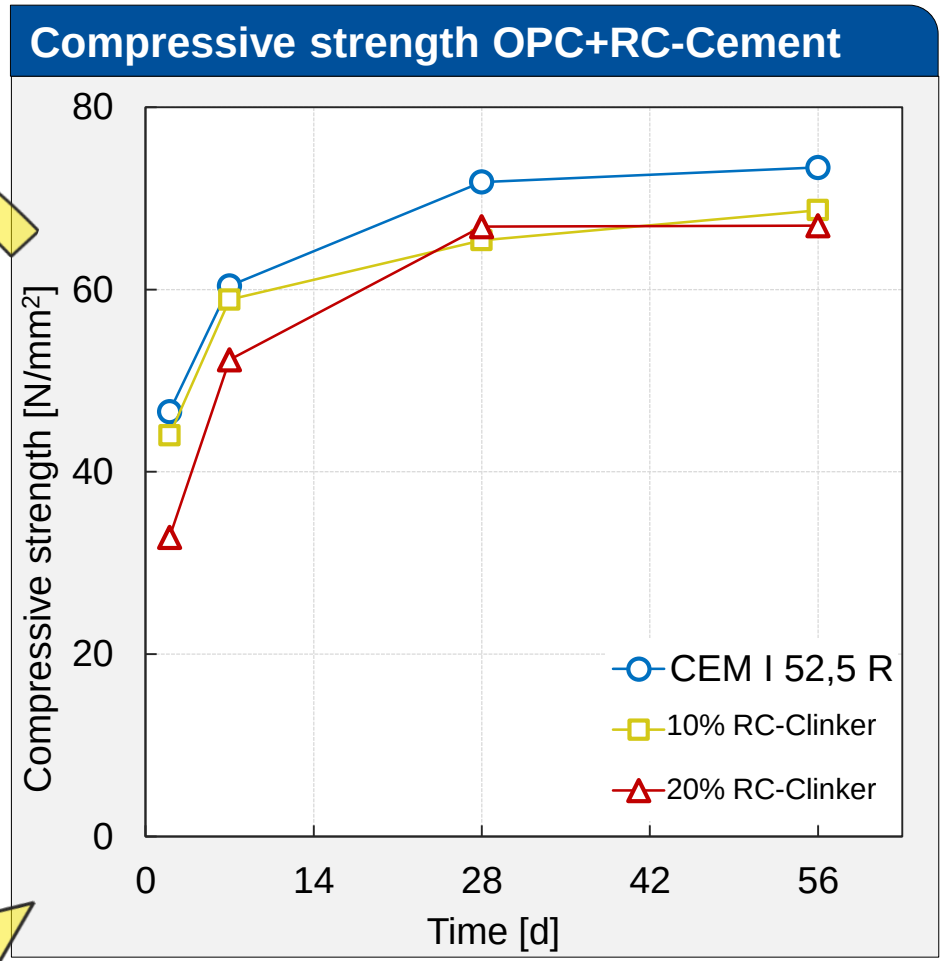


- Crushed concrete contains up to 70 % hardened cement paste → CaO, SiO_2
- **Hardened cement paste can be used as carbon-free raw material for new cement**
- Clinkering temperature can be significantly reduced → electrical heating



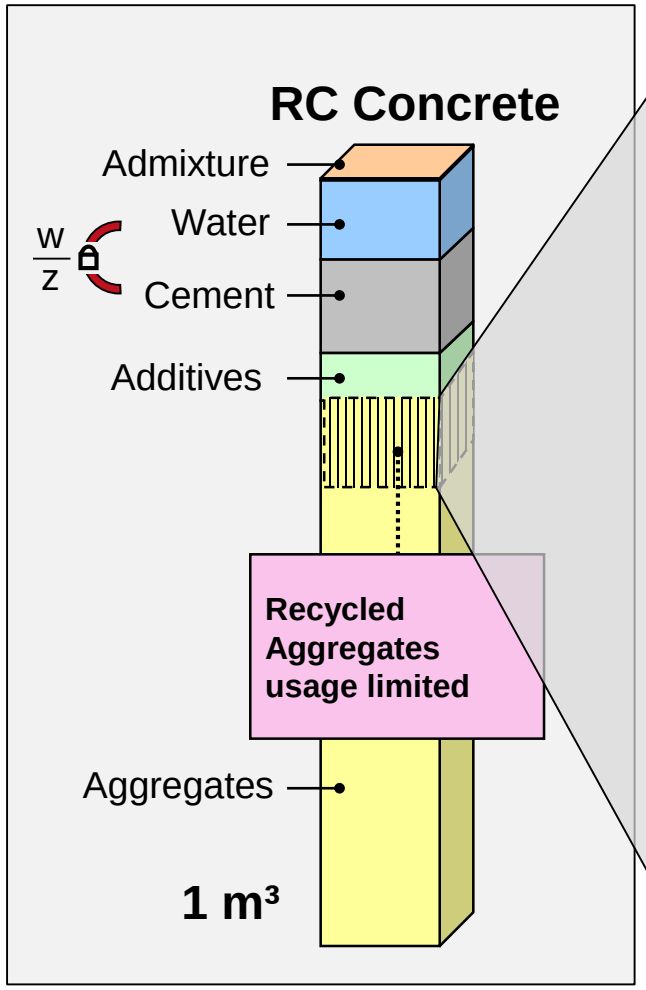
Electrical kiln

Image: ibuctec



Funded by: Bundesministerium für Wirtschaft und Klimaschutz

RC Concrete Composition

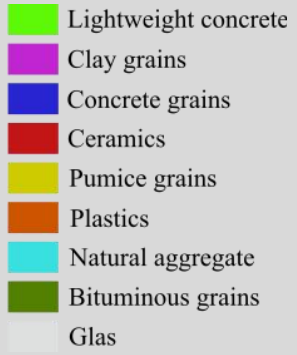


Type 1
- > 90 % crushed conc.
- < 10 % masonry

Type 2
- > 70 % crushed conc.
- < 30 % masonry

Type 3
- < 20 % crushed conc.
- > 80 % masonry

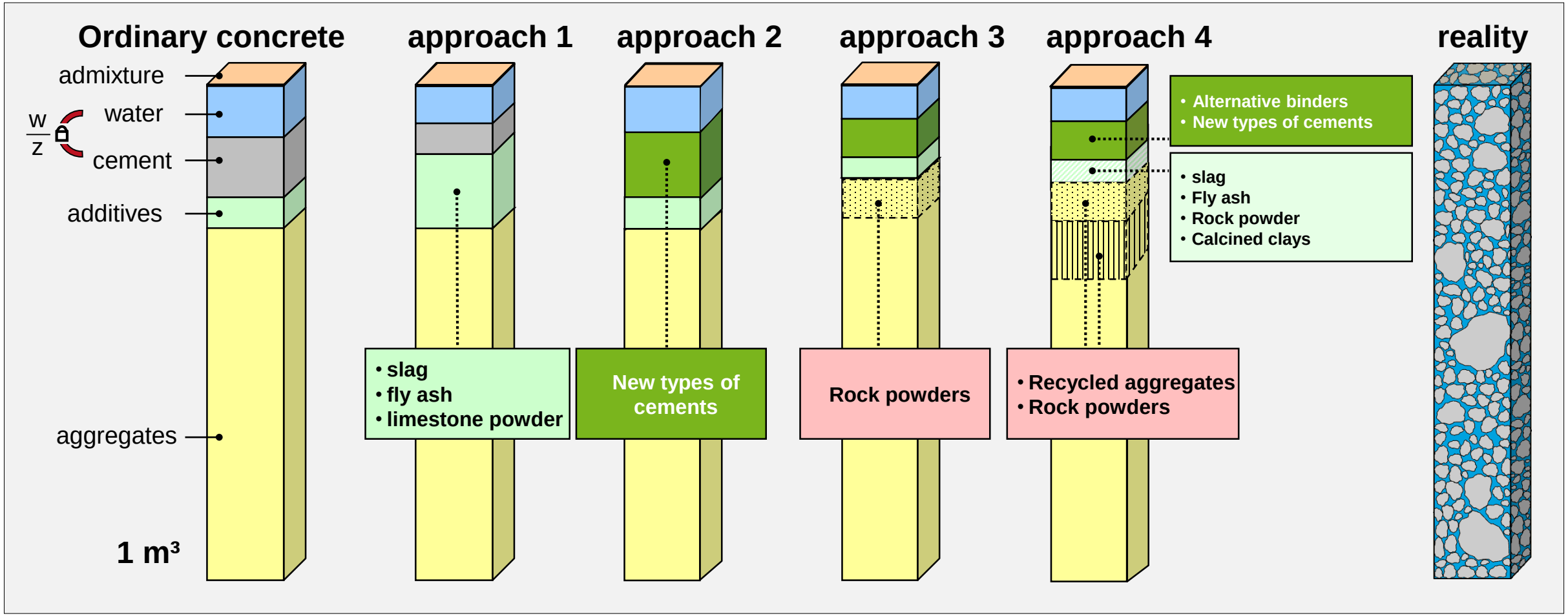
Recycled Aggregates



ReCyCONtrol

Problem:
- RC Material shows pronounced fluctuations in composition and properties
- RC Material shows pronounced water absorption → fresh concrete

Pathways to Low Carbon Concrete

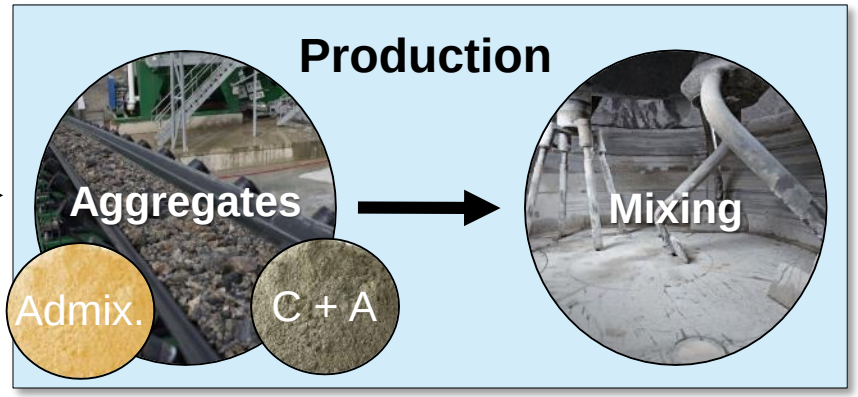


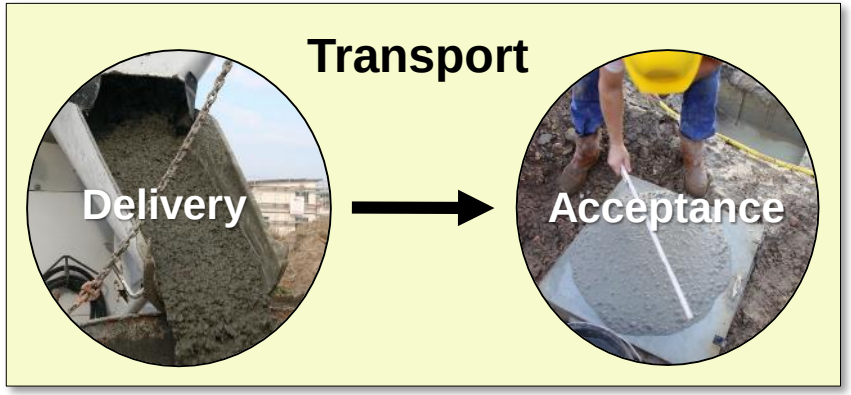
Concrete compositions are becoming significantly more complex!

Concrete 4.0 – Automated Process Control

Digital process chain
Intelligent control of concrete production

AI based hybrid reinforcement learning algorithms





Sensor Data
Control Command
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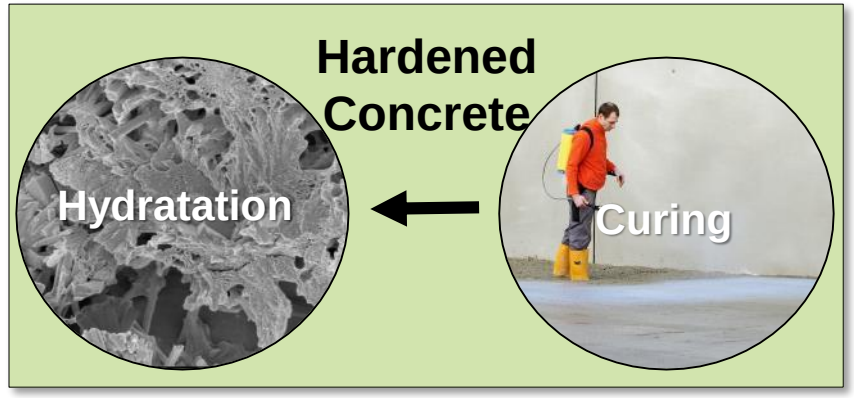
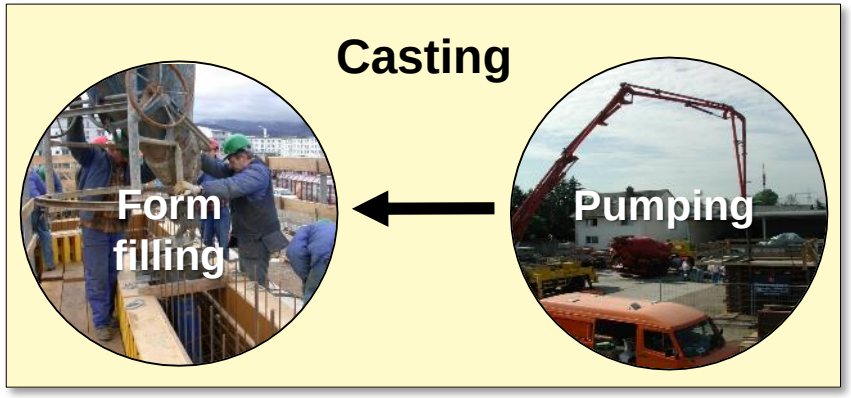
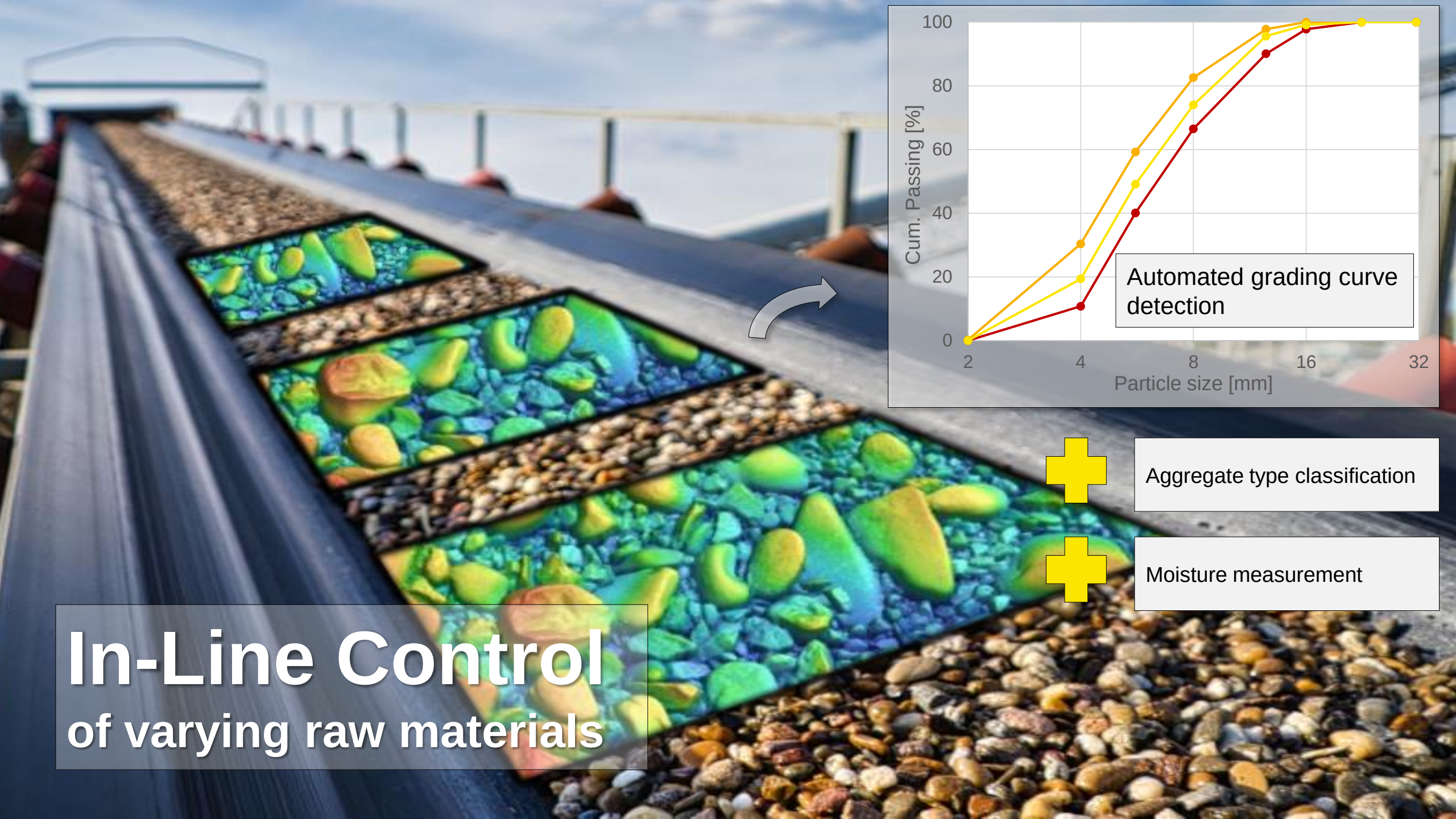





100
80
60
40
20
0
Cum. Passing [%]
2
4
8
16
32
Particle size [mm]
Automated grading curve detection
Aggregate type classification
Moisture measurement
In-Line Control
of varying raw materials

ReCyCONtrol

Leibniz Universität Hannover

Automated sensor based detection of fresh concrete properties in real time

AI-based concrete property control

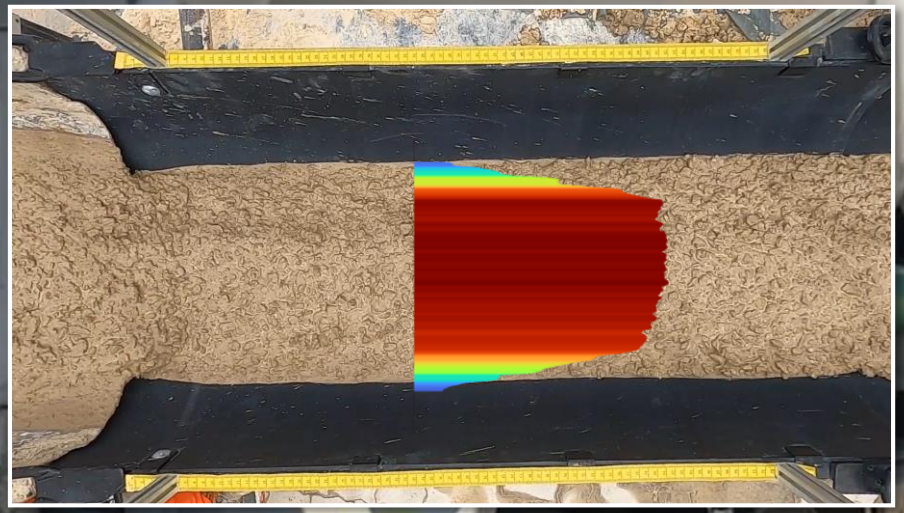
Funded by:
Bundesministerium für Bildung und Forschung

HEIDELBERGER BETON · MBCC · Pemat · BIK TRONIC · acemy · MoB · Leibniz Universität Hannover · BAW Bundesanstalt für Wasserbau

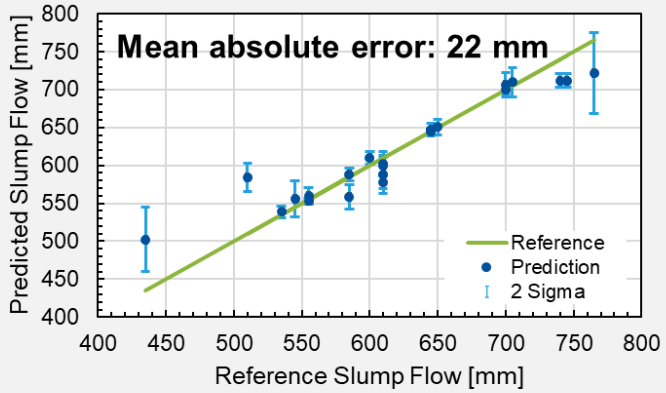
RGB-Kamera

Stereo-Kamera

Digital On-Site Acceptance Testing for In-line Quality Control



Slump flow δ



Fully automated process control from plant to construction site

Summary

- Concrete is and remains an indispensable building material, especially for infrastructure structures and buildings with high durability requirements
  - Climate change-related CO_2 reduction targets represent both a challenge and an opportunity
  - Concrete becomes more complicated in control especially with regard to recycled aggregates
  - Industry 4.0 techniques applied to concrete promise prounounced cost as well as CO_2-savings

Challenges in concrete sustainability are especially found in providing good fresh and hardened properties despite strong scattering in the raw materials

Thank you for your attention

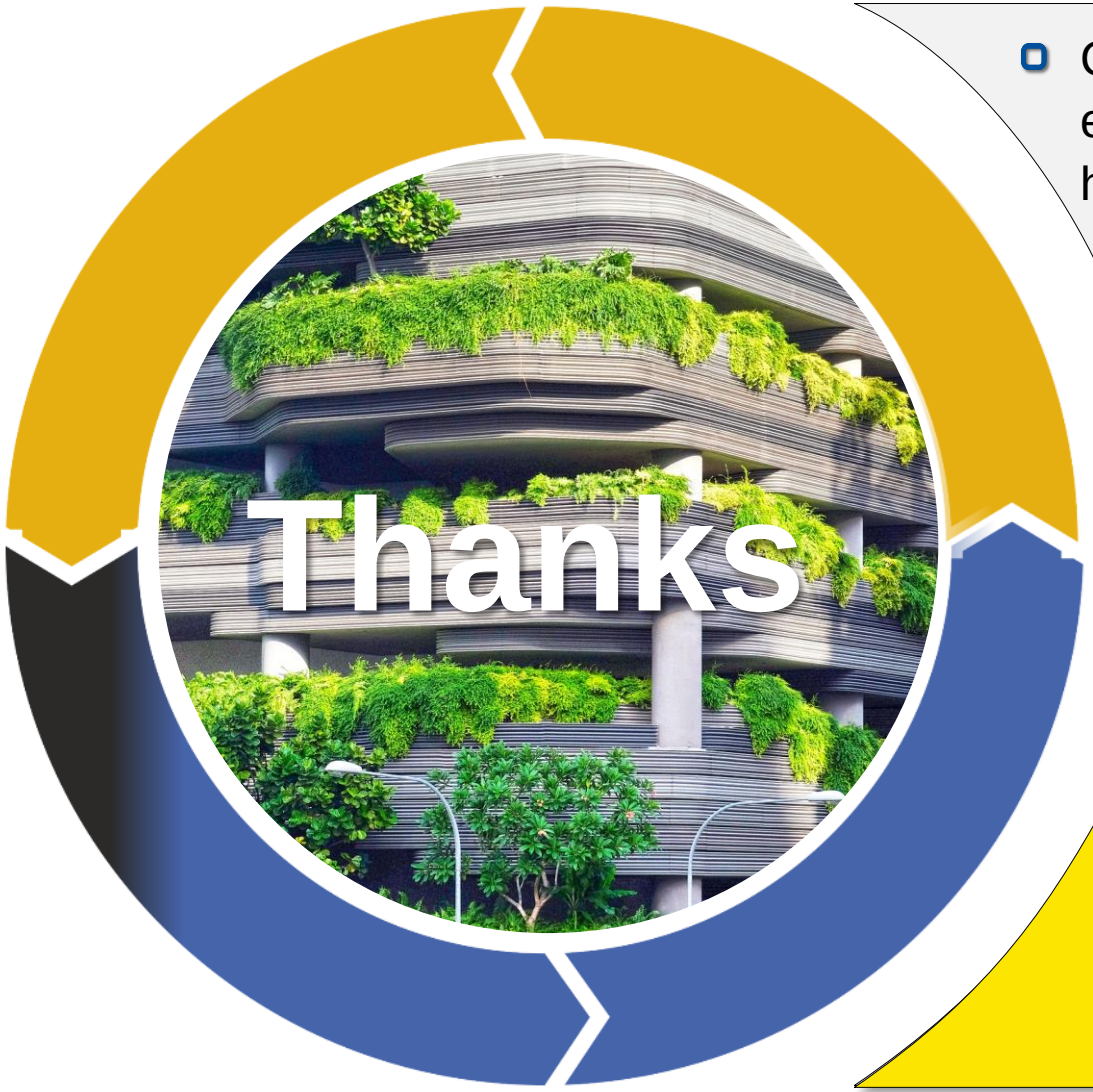


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Bild: https://citizensustainable.com/de/beton-nachhaltig/