Toward EU-Japan Collaboration for Development of Advanced Materials in Construction

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Features of the Construction

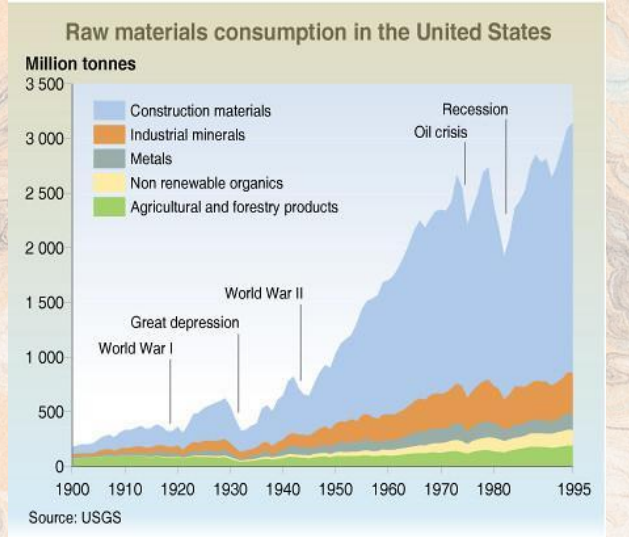
Large amount CO_2 emission

- Almost 50% of the total
  - ✔Operational 2/3
  - ✔Embodied 1/3

Huge resource consumption

- Much more than 50% of the total

Huge waste generation



Long service life

- Longer than 100 years

Thousands of years

Airplane: 20-25 years
Car: 10-15 years
TV: 10 years
Smart phone: 3-4 years

Development Objectives and Items to be Developed

- **Eternal circulation of building materials**
  - Versatile material performing a variety of functions
  - Strong bonding and easy debonding
- **Carbon neutrality in building construction**
  - Carbon mineralization with material balance
  - Control of crystal morphology of calcium carbonate
- **Longevity of buildings**
  - Modelling for material deterioration into performance degradation
  - Conservation and preservation materials for modern heritage buildings
- **Digital transformation in building construction and maintenance**
  - Additive manufacturing materials
  - Sensing & monitoring and NDT

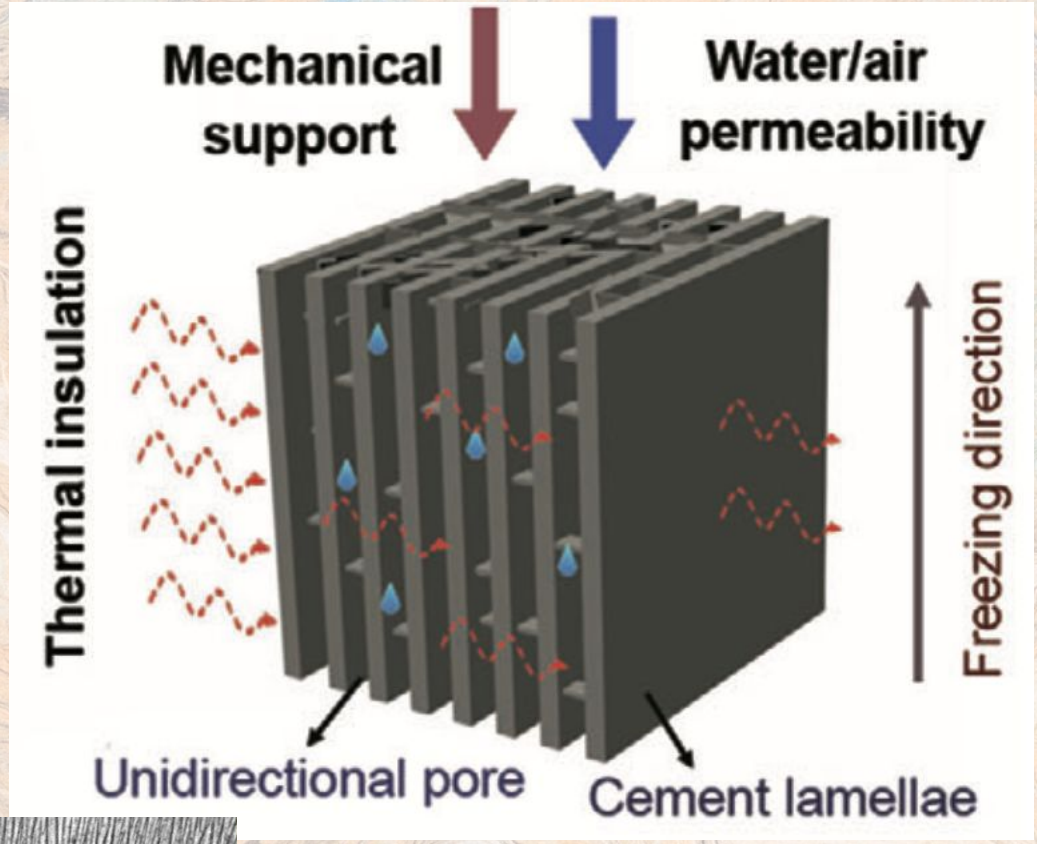
Eternal circulation of building materials

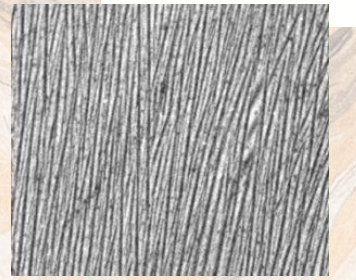
<u>Versatile</u> material performing a <u>variety of functions</u>

- **Single material**, e.g. cement, lime, etc.
- **Multi functions**, e.g. structure, thermal insulation, fire prevention, etc.

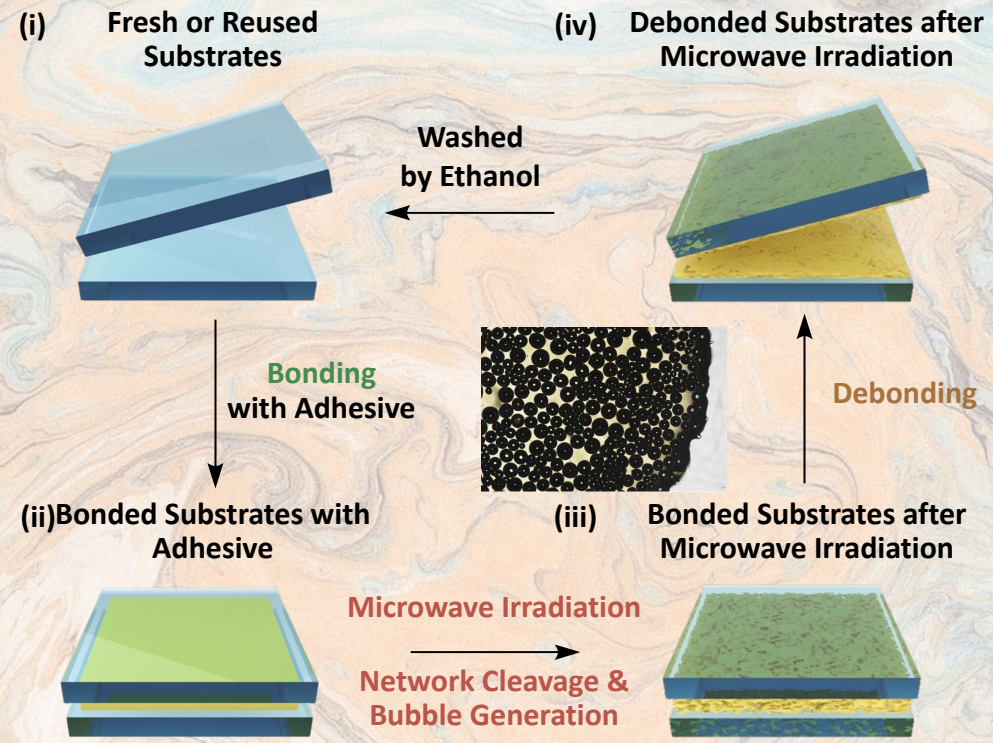
→ **Easy demolition and recycling**

Freeze casting of cement materials





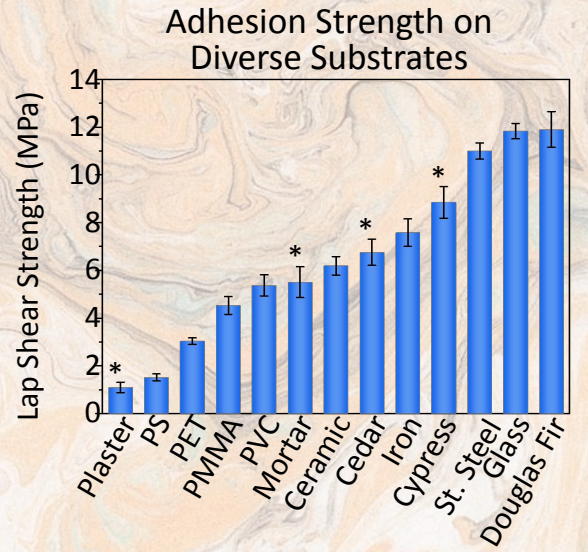
Eternal circulation of building materials

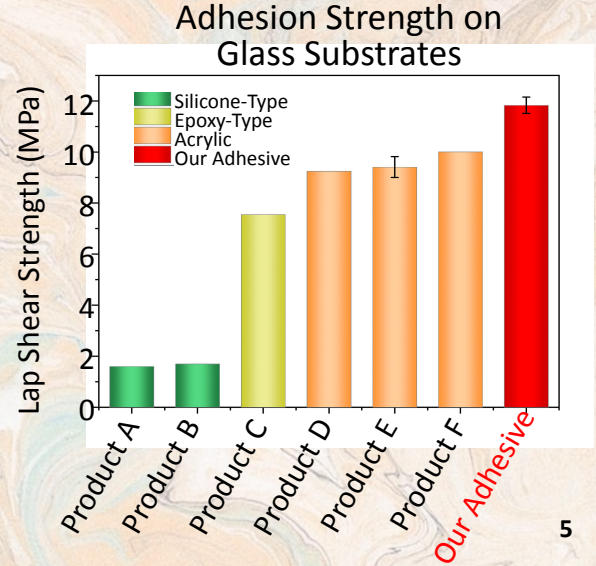


Strong bonding and easy debonding

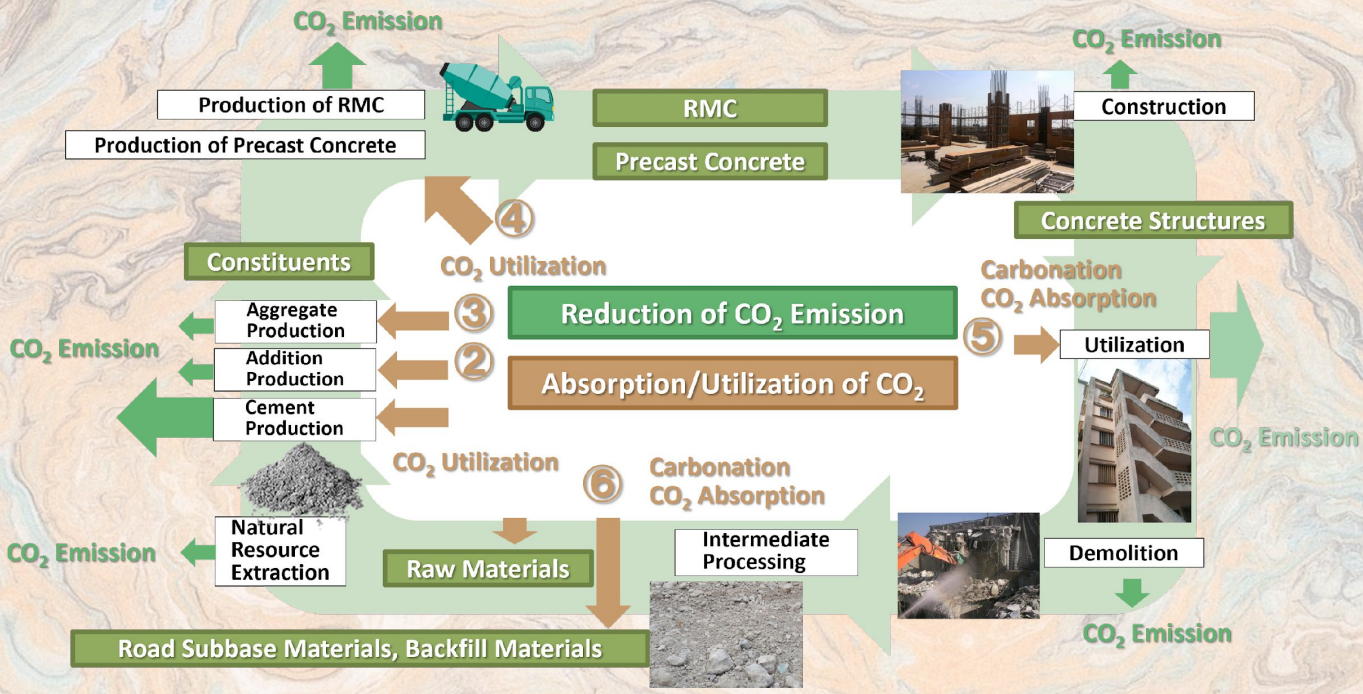
- **Stronger bonding** than conventional adhesives between any kind of materials
- **Heating** by electromagnetic induction

→ **Easy separation to promote reuse and recycling of building materials**





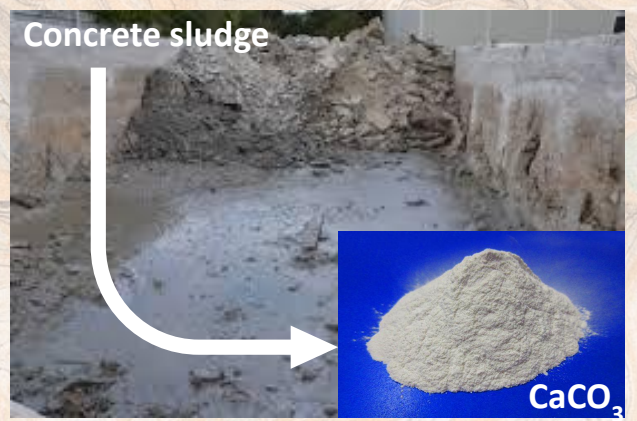
Carbon neutrality in building construction



Carbon mineralization with material balance

- **Sequestration of CO_2** from the atmosphere and exhausted gases in building materials, especially concrete
- **Carbonate utilization** as a concrete constituent and hardening by carbonation

→ **Promotion of "white carbon"**



https://www.ncic.co.jp/

$2CaO \cdot SiO_2$ (γ-C_2S) $+2CO_2 \rightarrow 2CaCO_3 + SiO_2$

https://www.kajima.co.jp

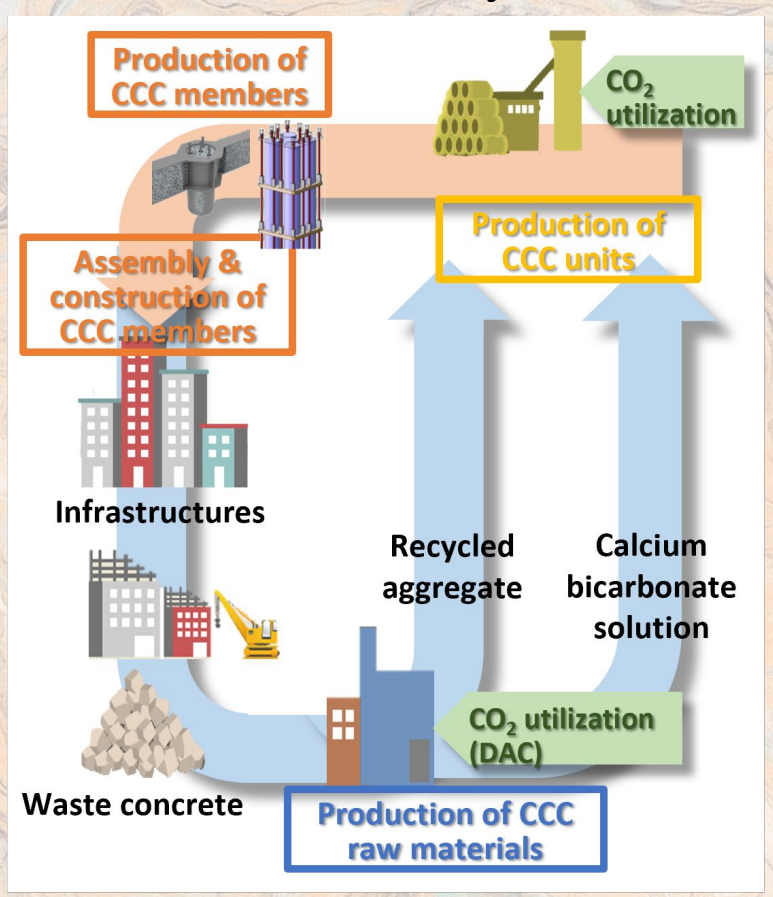
Carbon neutrality in building construction

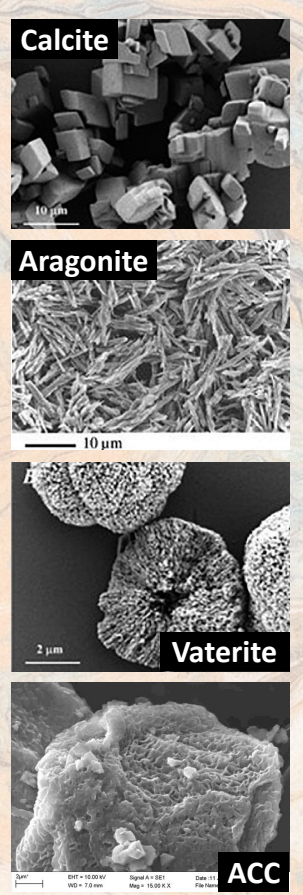
Control of crystal morphology of calcium carbonate

- **Recombination** of separated Ca and CO_2
- **Transformation** of unstable calcium carbonate into stable calcium carbonate as a binder

→ **Calcium carbonate circulation in construction**

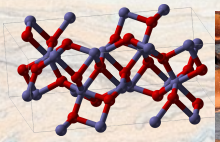
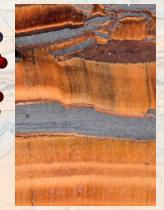
Moonshot Project





Ana M. Ferreira, Anna S. Vikulina, Dmitry Volodkin: Journal of Controlled Release, Vol.328, pp.470-489, 2020

Longevity of buildings


Chemical, biological, and electromagnetic actions

Chemical degradation phenomena
Changes in chemical composition and leaching of building materials

Mechanical action
Repeated freezing and expansion of internal moisture and frictional forces caused by walking and vehicle traffic

Physical degradation phenomena
Surface abrasion and internal micro-damage of building materials

Geometric degradation phenomena
Deformation and loss of building materials

Changes in physical properties
Decrease in strength and modulus of elasticity and increase in air and water permeability

Degradation of performance of building components

Degradation of building performance → Limit state

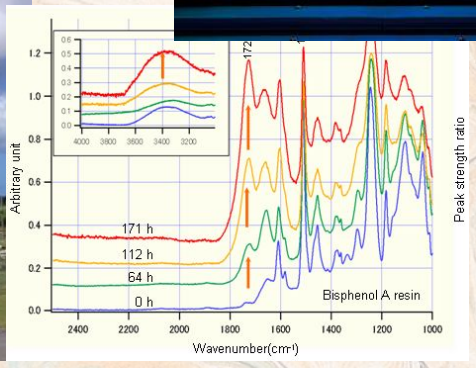
Modelling for material deterioration into performance degradation

- **Scientific exploration** of phenomena (microscale to macroscale)
- **Accelerated test** methods faithfully reproducing the natural environment

→ **Accurate prediction of building service life**

Natural environment

Accelerated test



Longevity of buildings

Conservation and preservation materials for modern heritage buildings

- **Authenticity-conscious reversible** repair materials for reinforced concrete heritage buildings
- Materials and technology maintaining **a sense of ruin**, i.e. stopping rebar corrosion as it is

→ **Permanent preservation of reinforced concrete buildings**

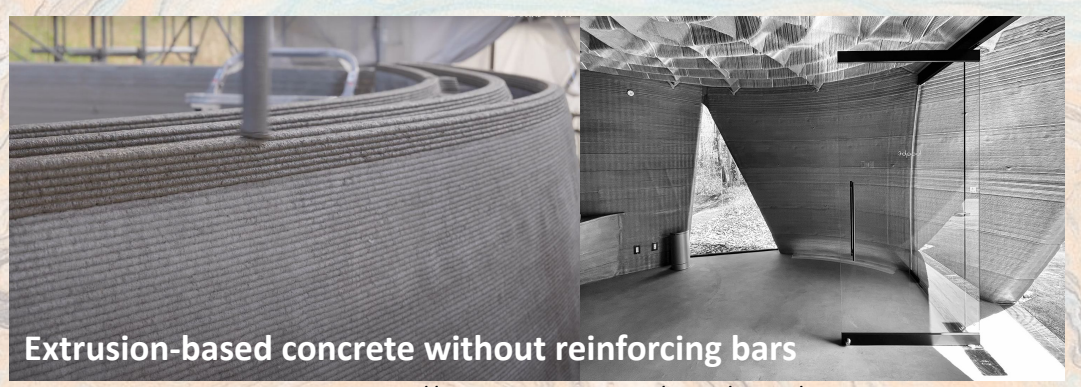
Registered as a World Cultural Heritage in 2015

Digital transformation in building construction and maintenance

Additive manufacturing materials

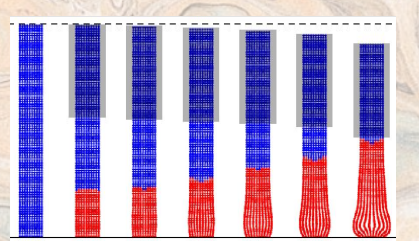
- Materials ensuring **buildability** without plastic collapse or buckling
- **Computer simulation** on buildability

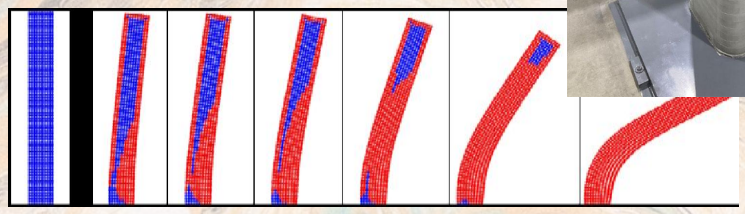
→ **Breakaway from labor-intensive industries through automated construction and optimally shaped buildings**



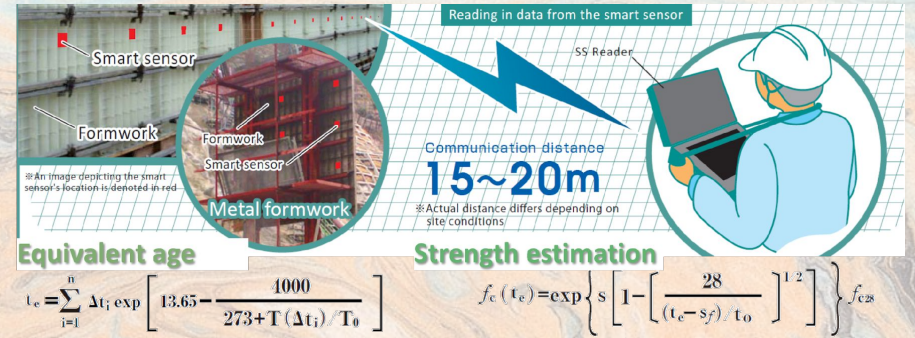
https://www.obayashi.co.jp/news/detail/news20230425_1.html#

https://www.shimz.co.jp/company/about/news-release/2024/2023061.html





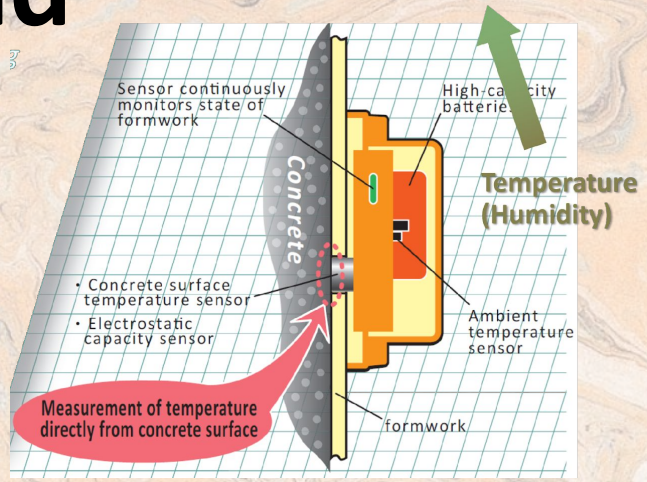
Digital transformation in building construction and maintenance

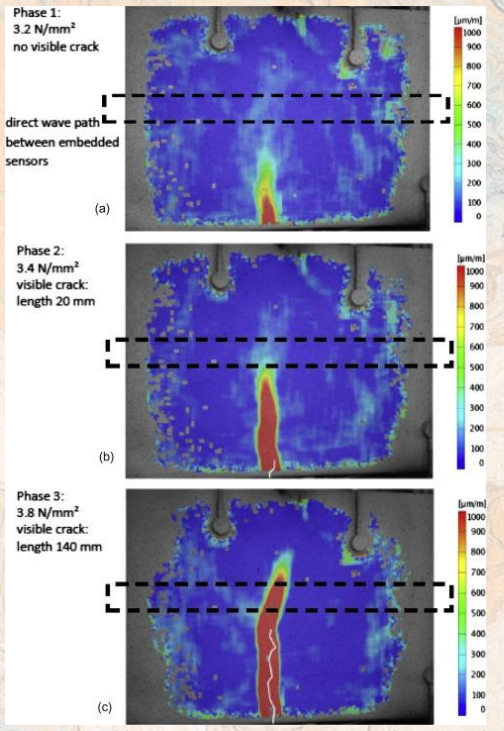


Sensing & monitoring and NDT

- Materials responses to loads, forces and actions, e.g. stress, deformation, carbonation, etc.
- Micro-climate conditions, e.g. temperature, moisture, pH, etc.
- Materials properties, e.g. ultrasonic propagation speed, etc.

→ **Breakaway from labor-intensive industries and highly reliable construction & maintenance**



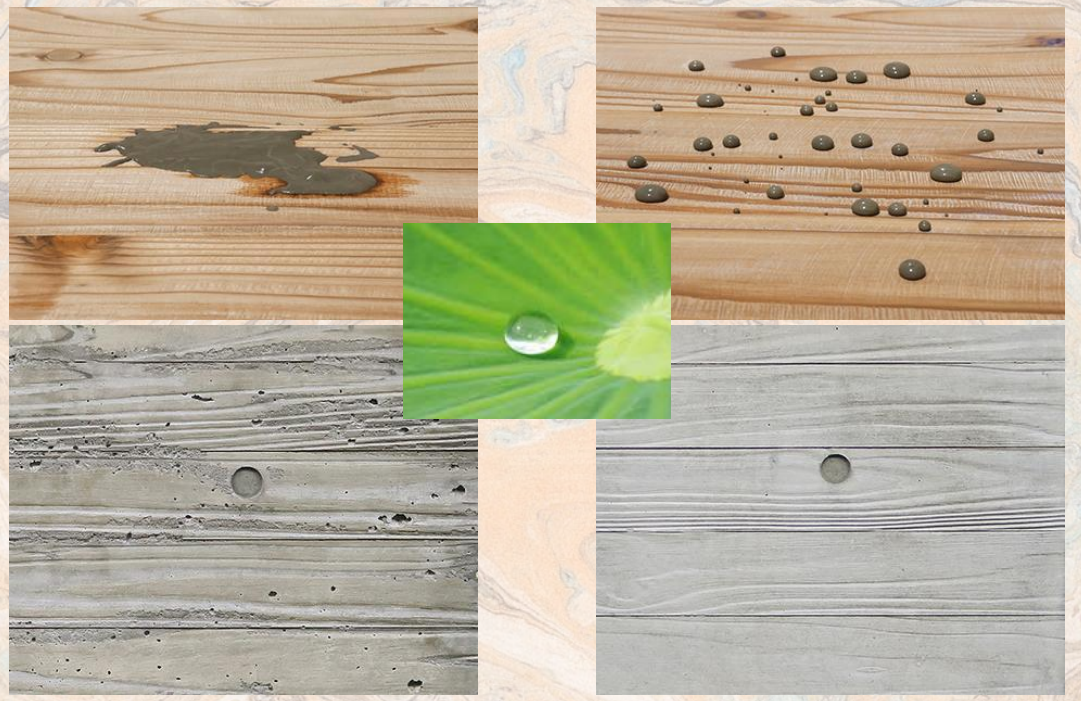


https://www.sciencedirect.com/science/article/abs/pii/S0013794415004348

Other areas of interest

- ***Biomimetics***, ***biomimicry***, ***bio-inspired*** *and* ***biophilic*** *building materials*
- ***Autonomous*** *(****self-healing***, ***self-cleaning****) building materials*
- *Material structure simulation by* ***molecular dynamics***
- *Scientific approach for* ***traditional vernacular*** *building materials*

Super water-repellent formwork with a lotus leaf surface pattern



https://www.shimz.co.jp/en/company/about/sit/topics/topics04/

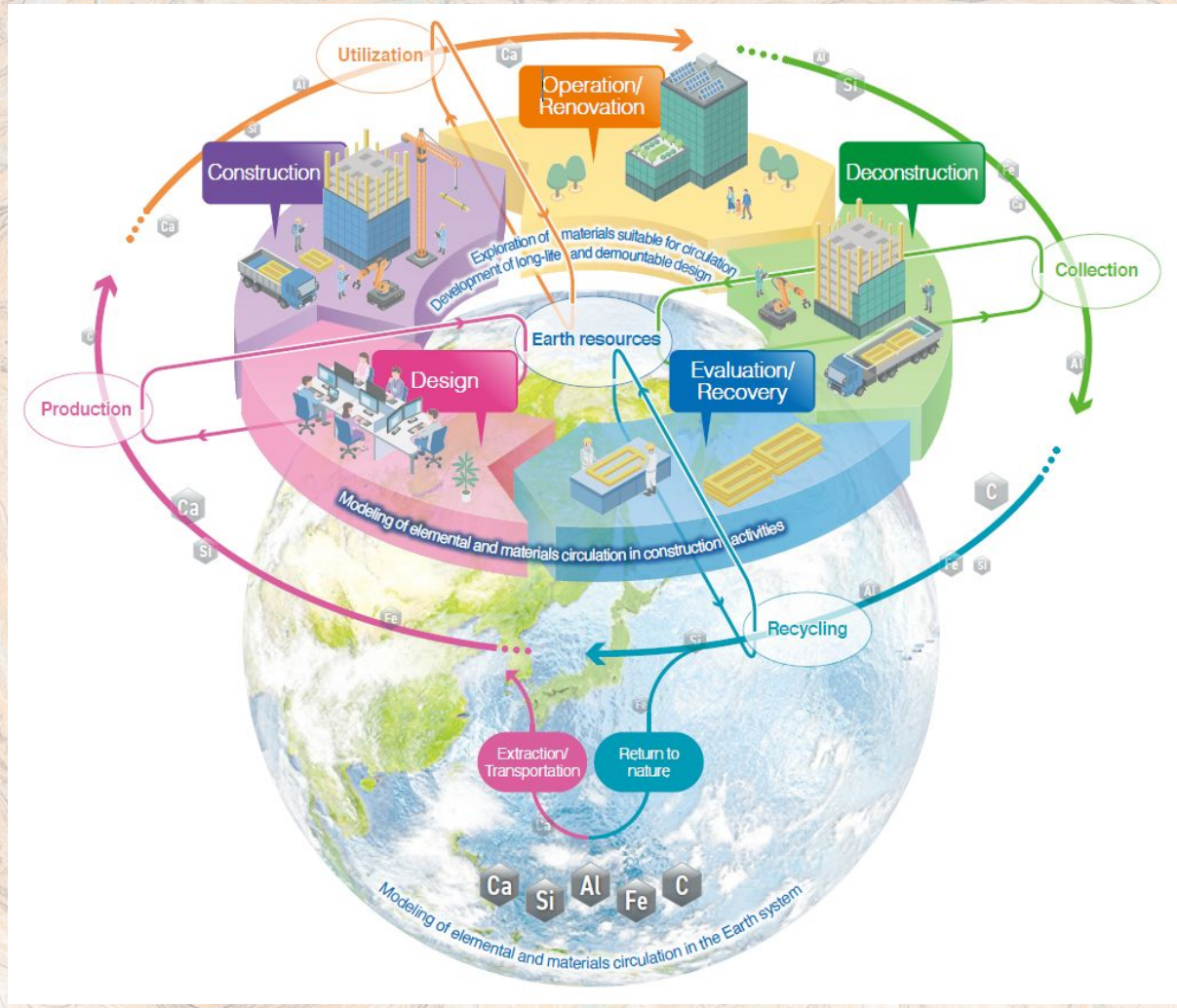
Adobe

Lacquer

What the construction field should be

- ***Activities to the Earth***
- ***Activities with the Earth***
- ***Activities for the Earth***

The circulation of building materials must be in affinity with, or isolated from, the circulation in the earth.



It is hoped that in the near future, **joint research and development** on advanced materials between EU and Japan in the construction field will actually begin, leading to a **safer**, more **comfortable**, and more **economical** built environment.

Thank you for your kind attention!