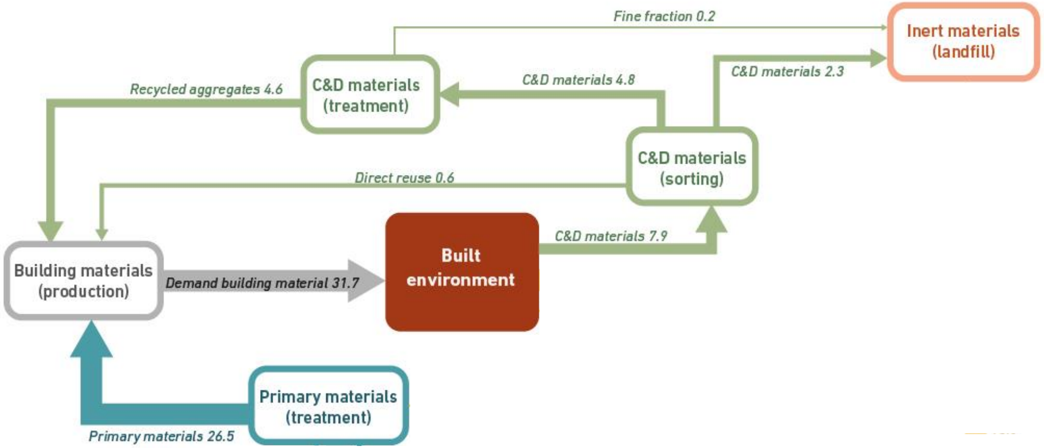
ETH zürich

Chancen und Grenzen von Erdbeton

Prof. Dr. Guillaume Habert
Professur für Nachhaltiges Bauen

Terres de Paris. 2017. Joly and Loiret. Credit: Schnepp Renou

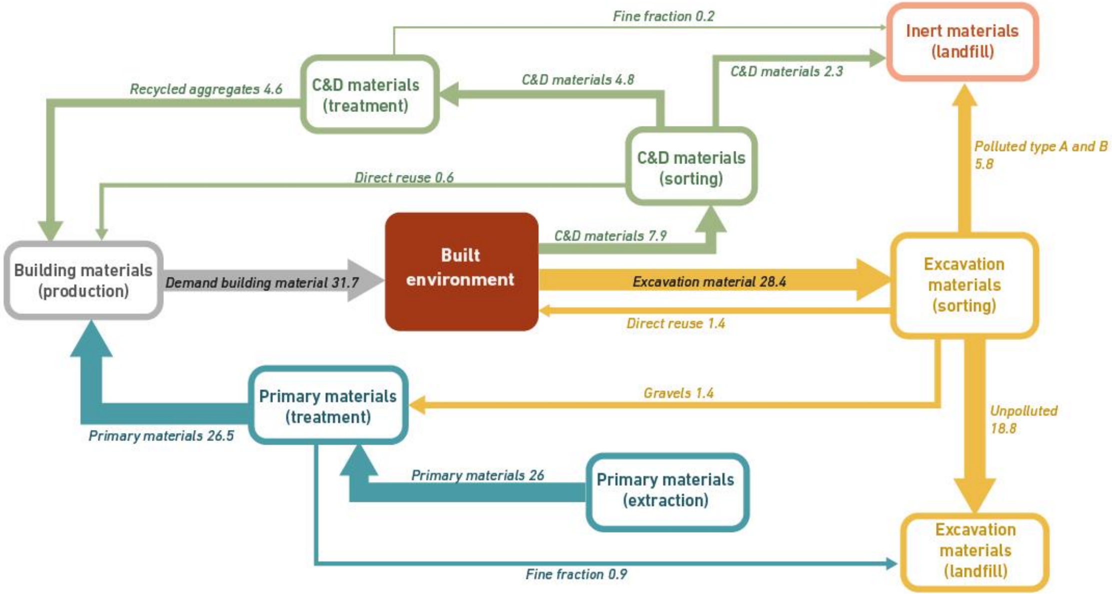
70% of construction & demolition waste are already recycled
Closing the remaining landfilled material can supply less than 10% of current demand for new materials



Sce: Material flow in Switzerland in 2018. Expressed in 10^6.m^3/yr (KAR Model 2018, Adapted from Rübli, 2020)

Excavation material flow is currently not circular *(but is not a C&D waste)*
Closing this flow can supply 75% of current demand for new materials

Credit: Schnepp Renou



Sce: Material flow in Switzerland in 2018. Expressed in 10^6.m^3/yr (KAR Model 2018, Adapted from Rübli, 2020)

Earth is the most abundant material in urban context

Sce: Recycling plant of SPL-Eurovia (Gennevilliers, France) Schnepp-Renou for the Exhibition Terres de Paris de la matière au materiau. Pavillon de l'Arsenal PE Loiret S Joly 2017

Using earth construction is well known vernacular technique

Sce: Ksar Aït-Ben-Haddou – Marocco - @CRAterre

Using earth construction is well known vernacular technique
But also used after industrial revolution in European urban context

Sce: Rammed earth wall, 6 storey (1870), Lyon – France

Using earth construction is well known vernacular technique
But also used after industrial revolution in European urban context

Sce: Rammed earth wall, 6 storey (1870), Lyon – France
Six-story residential building using rammed earth technique in Weilburg a. d. Lahn, built by W.J. Wimpf around 1830

Low durability of earth material is as much a myth as the high durability of concrete material…

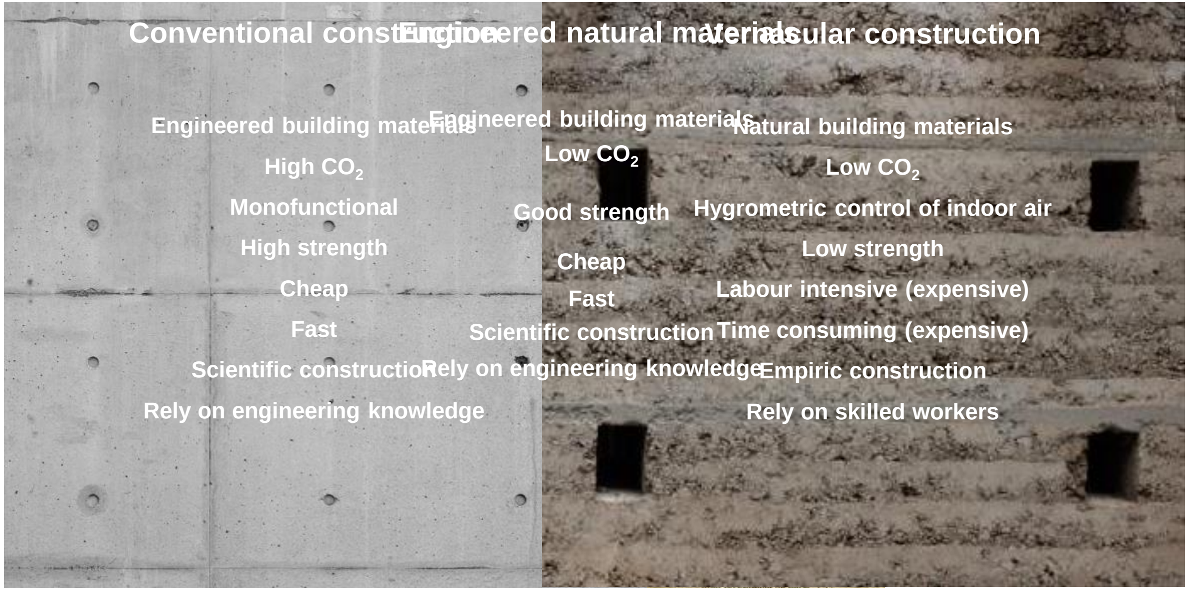
Sce: Six-story residential building using rammed earth technique in Weilburg a. d. Lahn, built by W.J. Wimpf around 1830
First 2 storey concrete house, Coignet architects (1853) St Quentin-Fallavier, France

Difficulties:

time and labour intensive technique,
difficult to adapt to the current urban development pace

Sce: rammed earth wll, Portugal - CRAterre

Need for engineered natural materials



Emergence of new techniques
to be faster and economically viable
Prefabricated rammed earth

Sce: Prefabricated rammed earth, Vergely architects, St Quentin Fallavier (France)

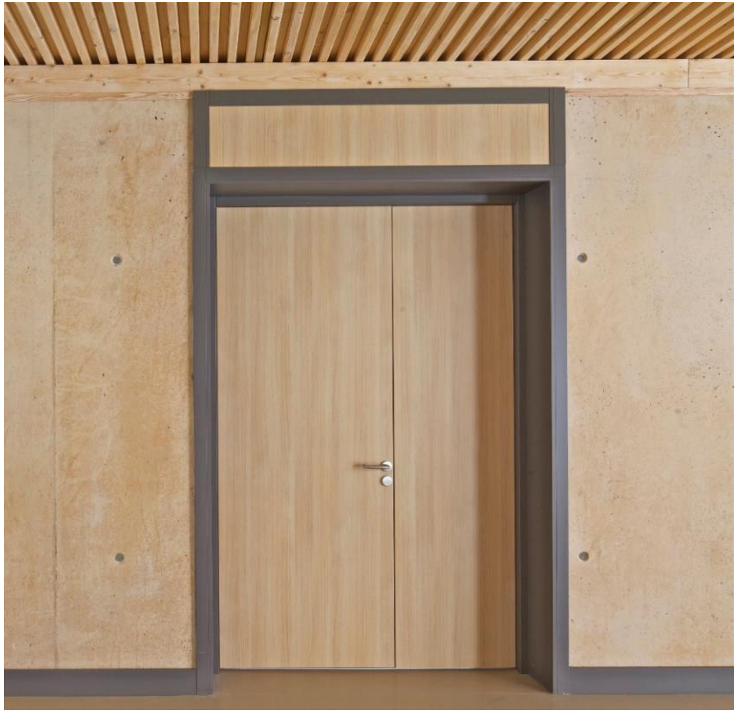
Emergence of new techniques to be faster and economically viable
Prefabricated rammed earth

Sce: *Prefabricated rammed earth construction, Ricola Building (Switzerland), Martin Rauch*

Emergence of new techniques
to be faster and economically viable
Poured earth

Pouring stabilised earth
Maison des associations. Mil'lieux architects. 2014

Vibrating stabilised earth
Maison des associations. Mil'lieux architects. 2014



Final structural wall after demoulding and drying
Maison des associations. Mil'lieux architects

Emergence of new techniques to be faster and economically viable

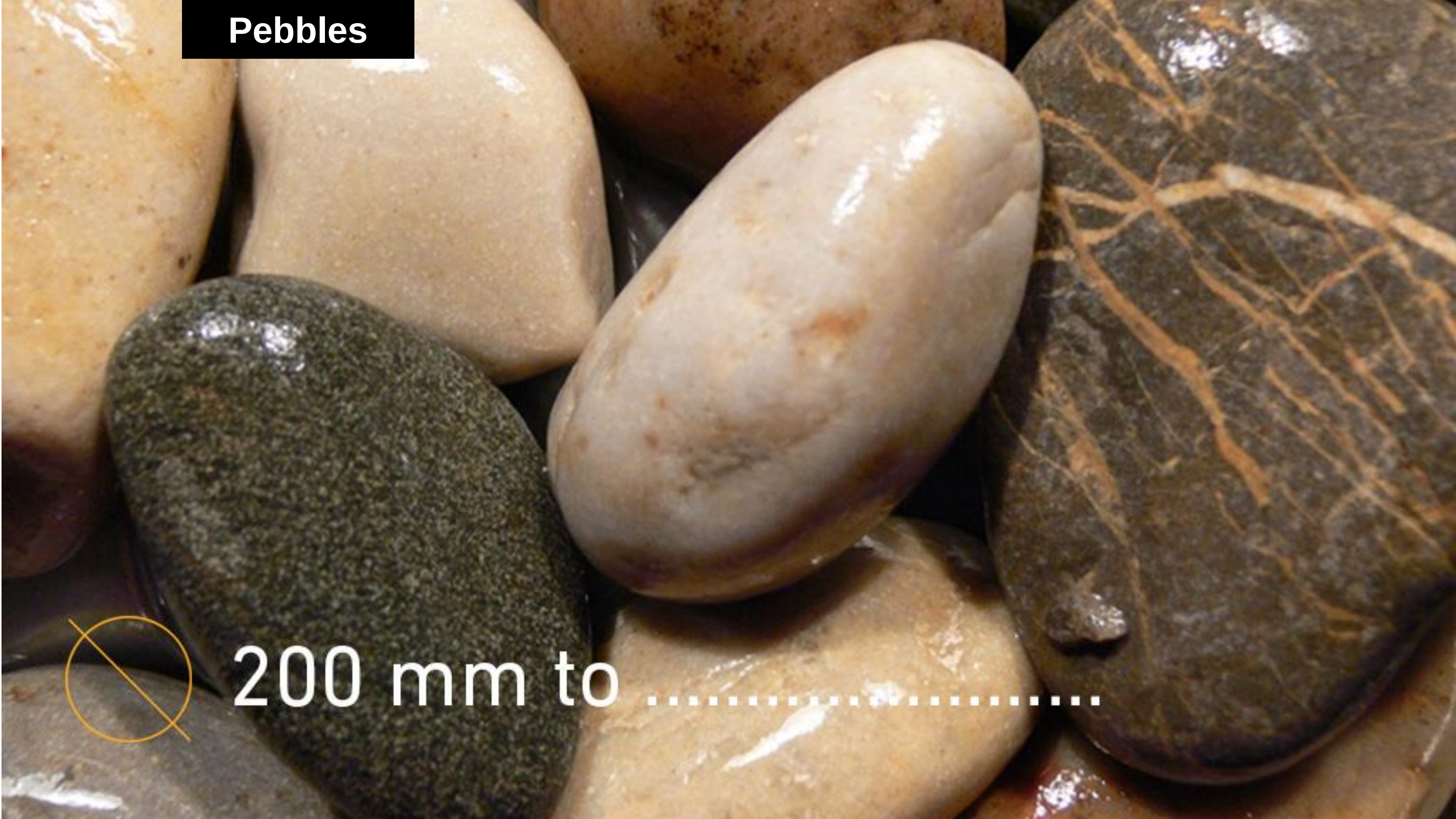
Poured earth

Swiss National Science Foundation

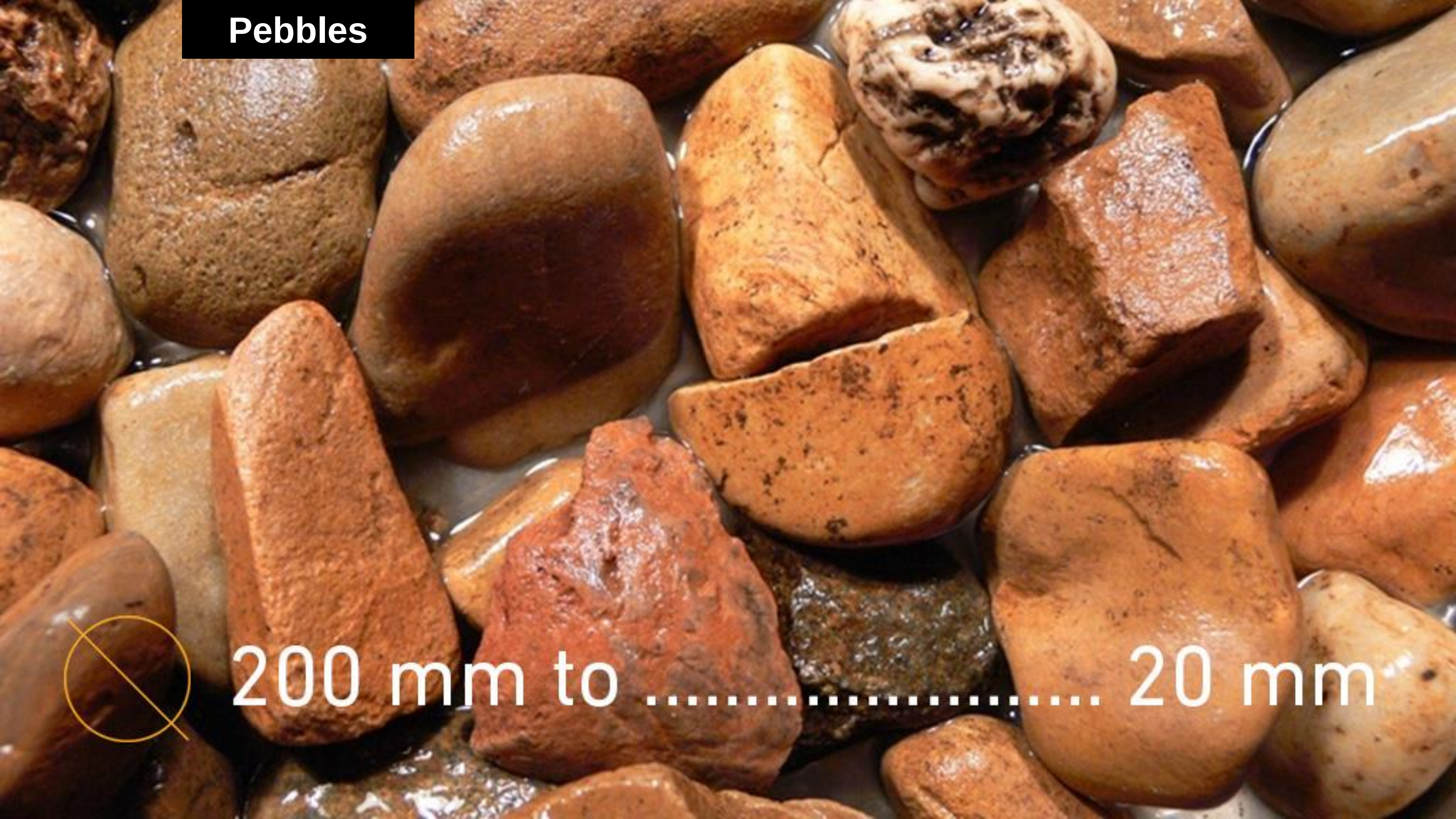
oxara

Sce: PhD Gnanli Landrou, Self Compacted Clay Concrete, 2018, ETH - SNF research funding

How does it work?


Pebbles
200 mm to ....

Pebbles



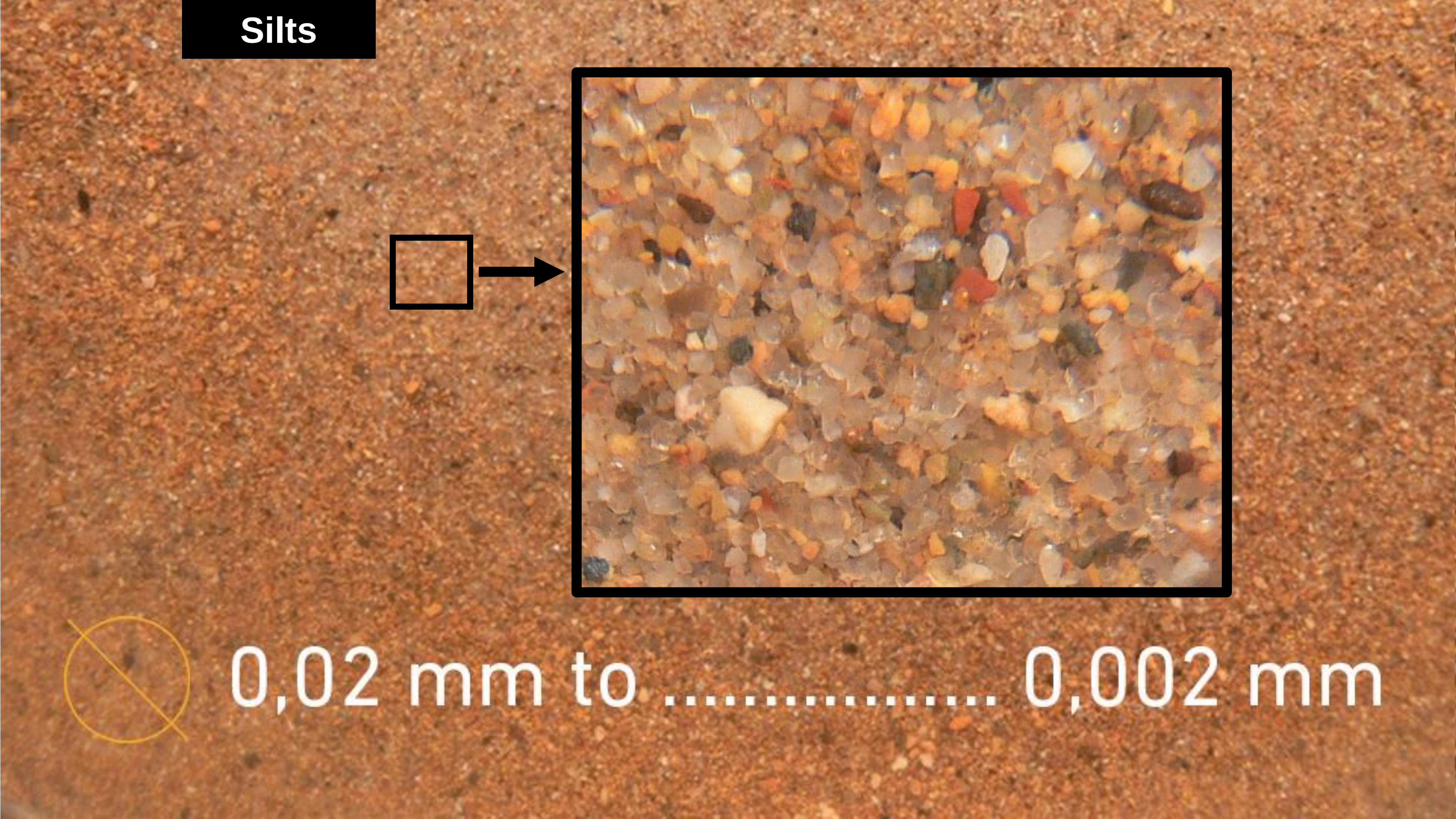
Gravels

Gravels

Gravels

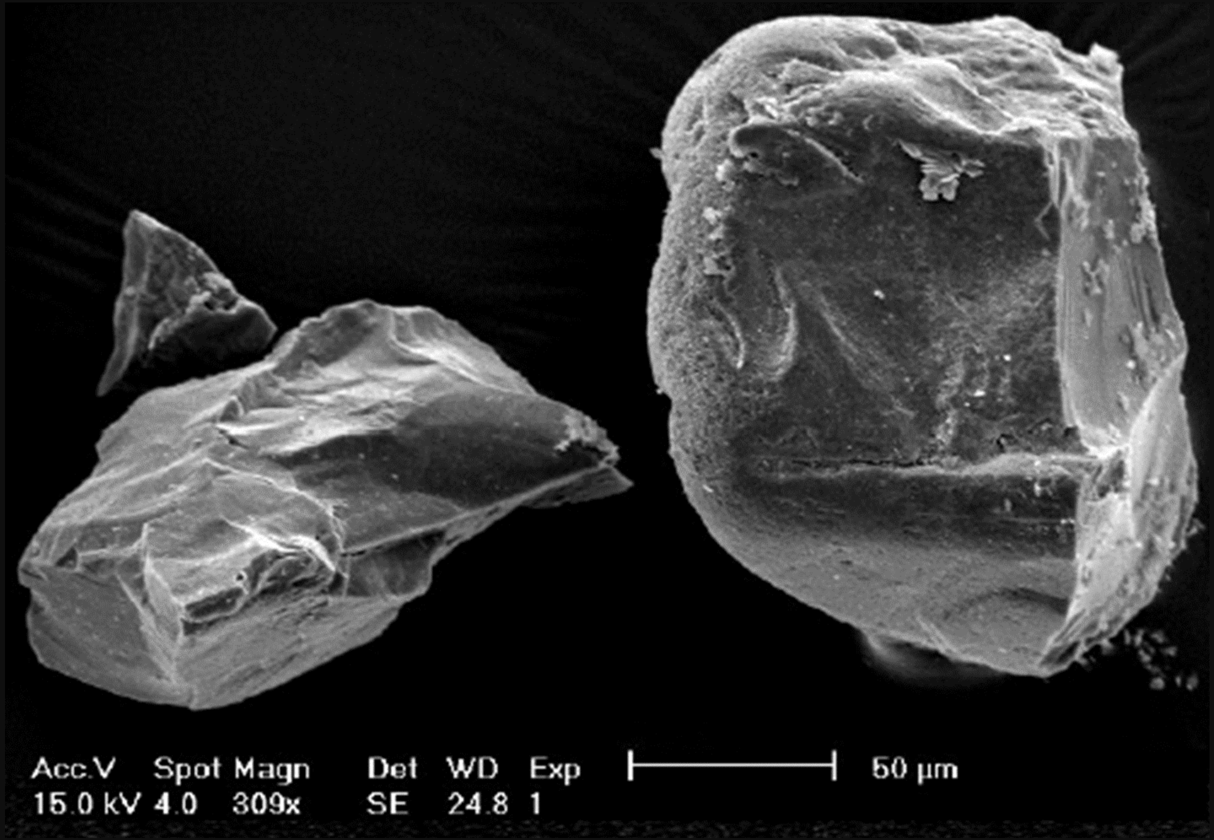
Sands

Sands

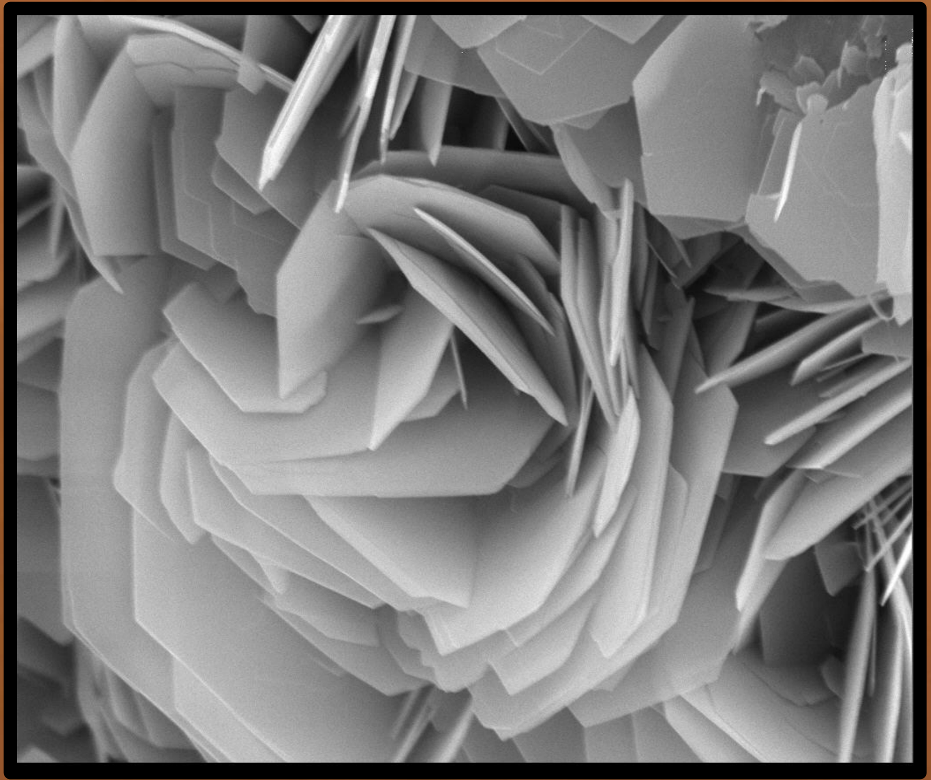

Silts
0,02 mm to .... 0,002 mm

Pebbles – Gravels – Sands – Silts

Spherical grains

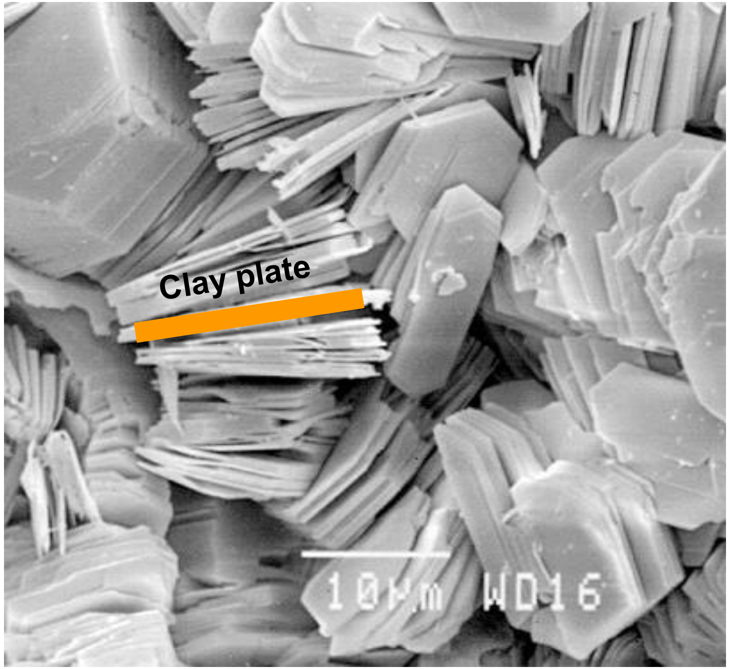


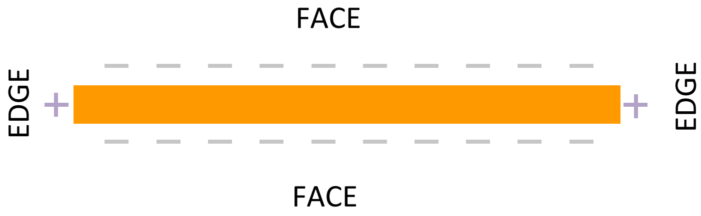
Clays



⌀ < 0,002 mm

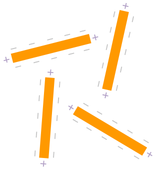
Clay particles are flat and charged





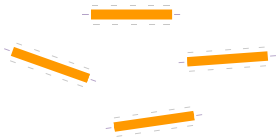
SCE: SEM from kaolinite. Bâtir en Terre: du grain de sable à l’architecture. Fontaine et Anger . 2009

Poured earth mechanism



0. Clay in water

\+
dispersant
Change polarity
Sodium Hexametaphsphate (NaHMP)
Sodium silicate (NaSil)
Polyacrylate
…



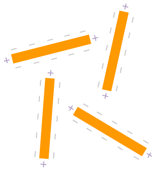
1. Deflocculated state

Change edge polarity
All free water is available

\+
coagulant
brings back to initial state

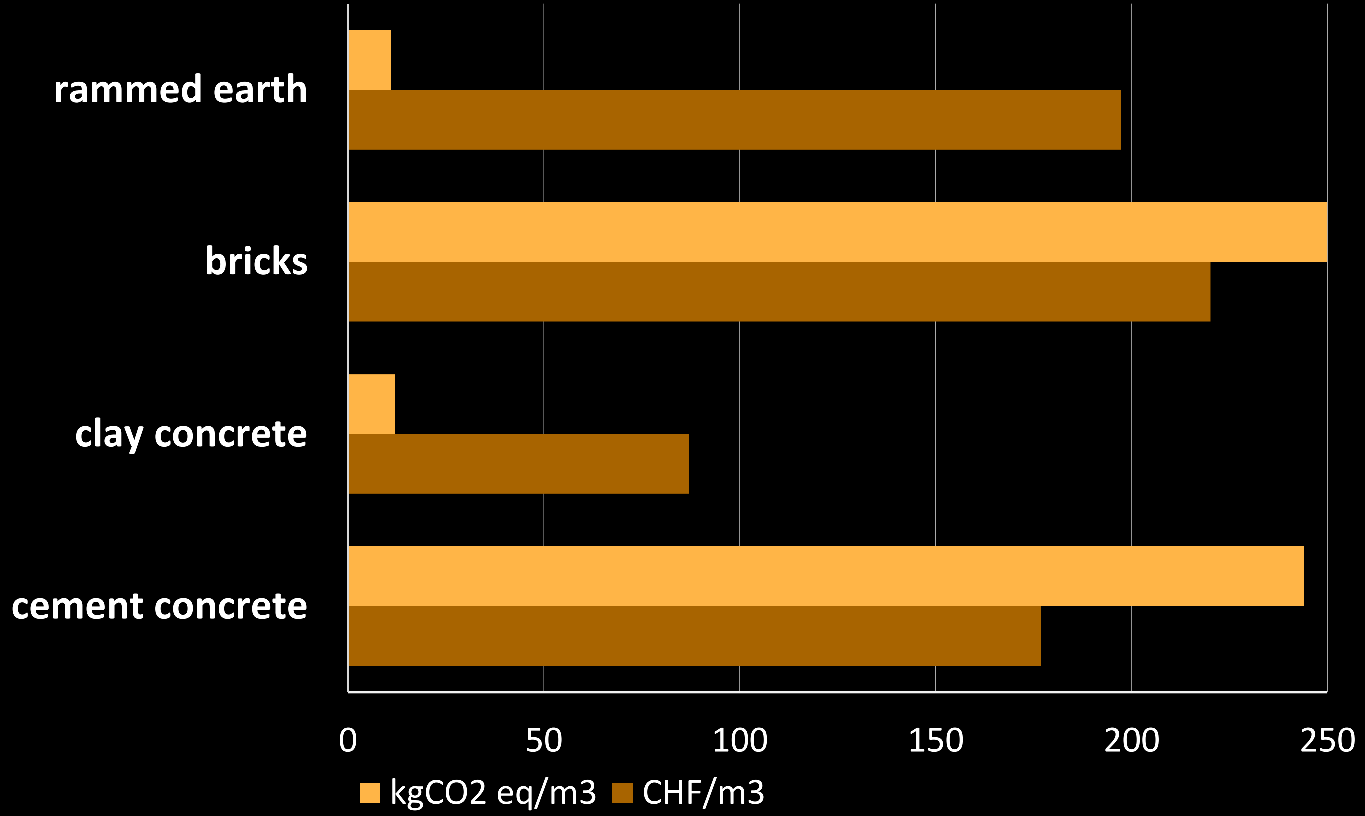
Calcium based
-> cations Ca^{2+}
(lime, wood ashes,…)

Magnesium based
-> Cations Mg^{2+}
(Magnesium oxide, Magnesium sulfate,..)

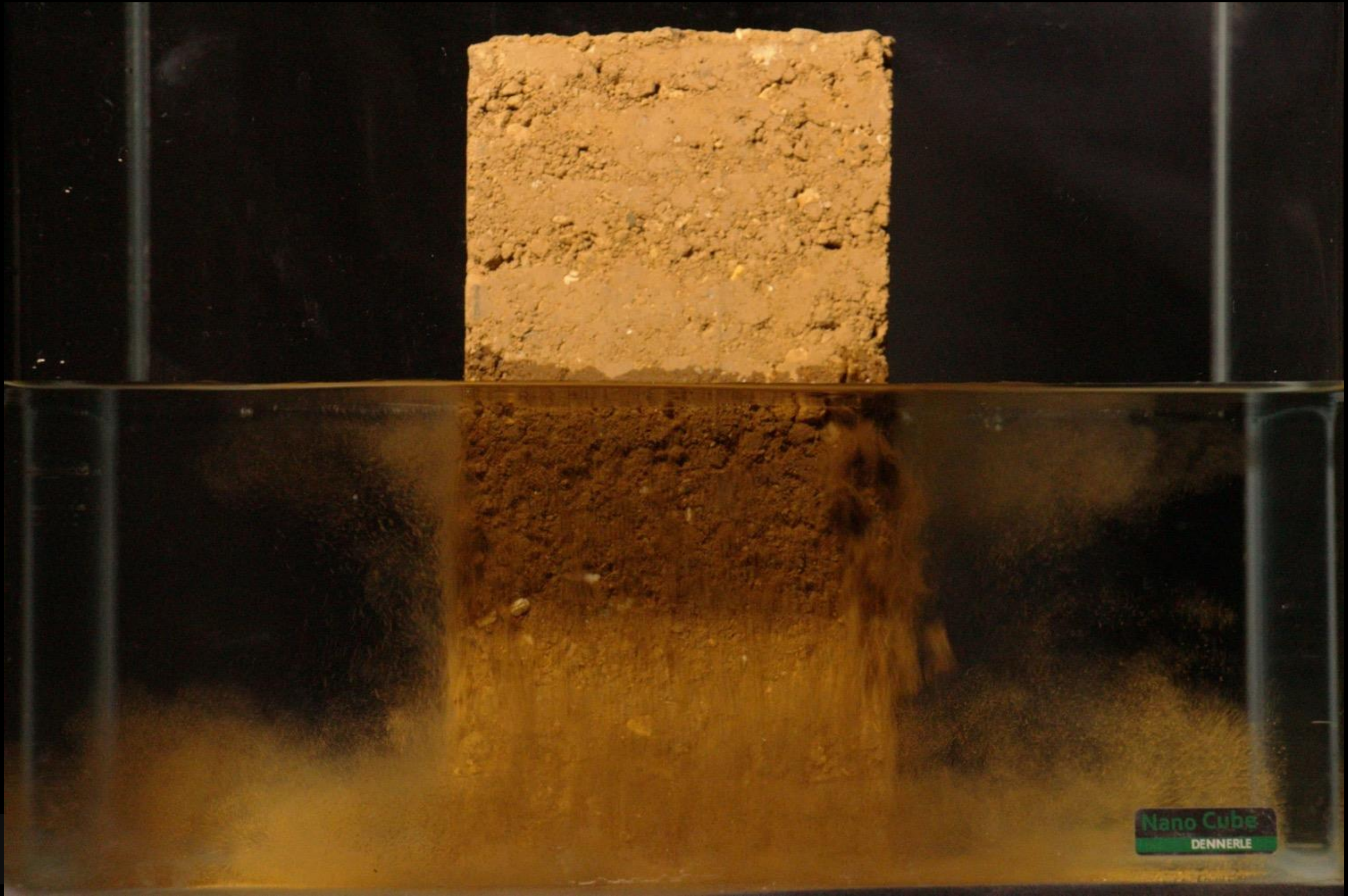


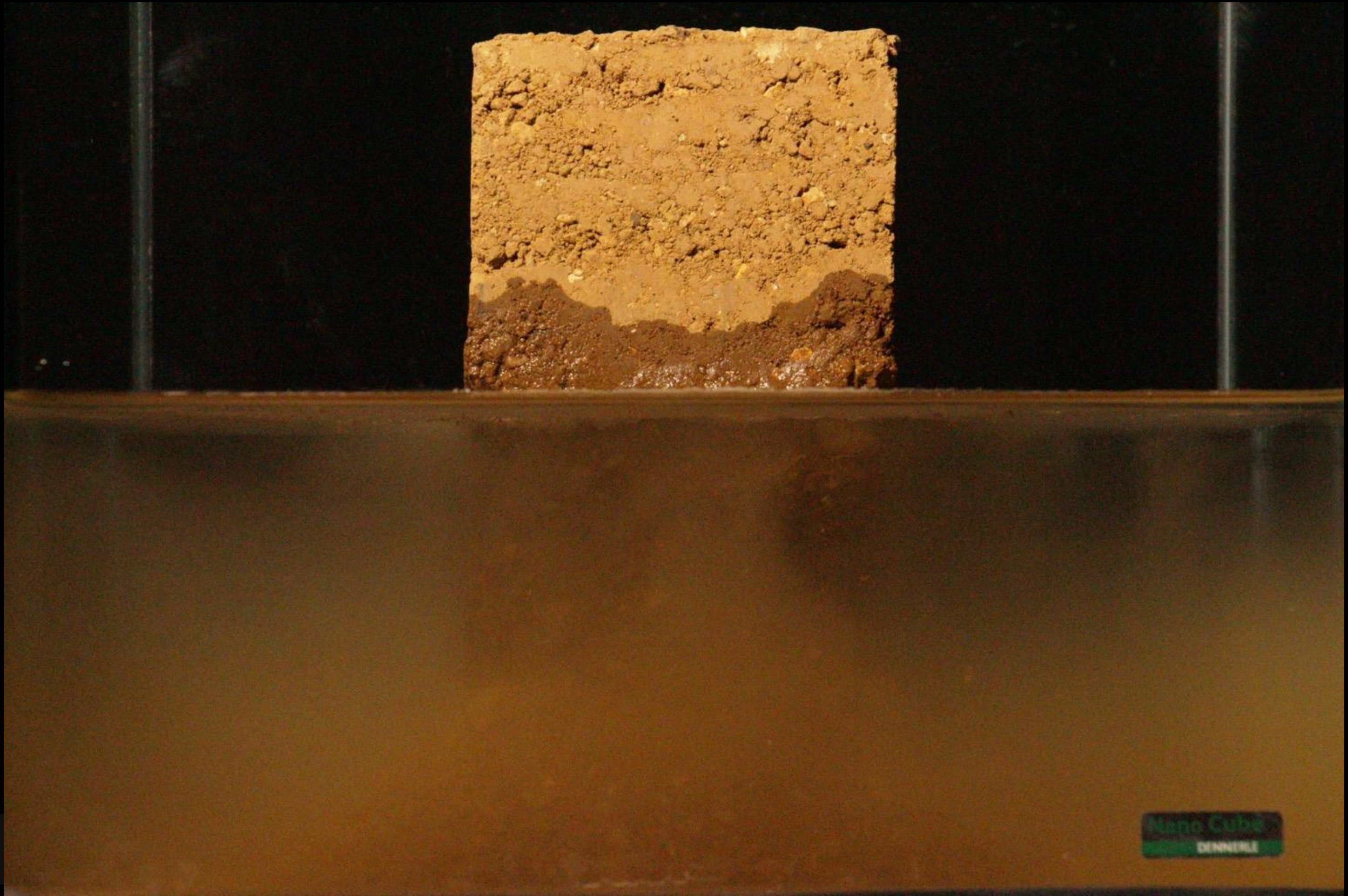
2. Flocculated state

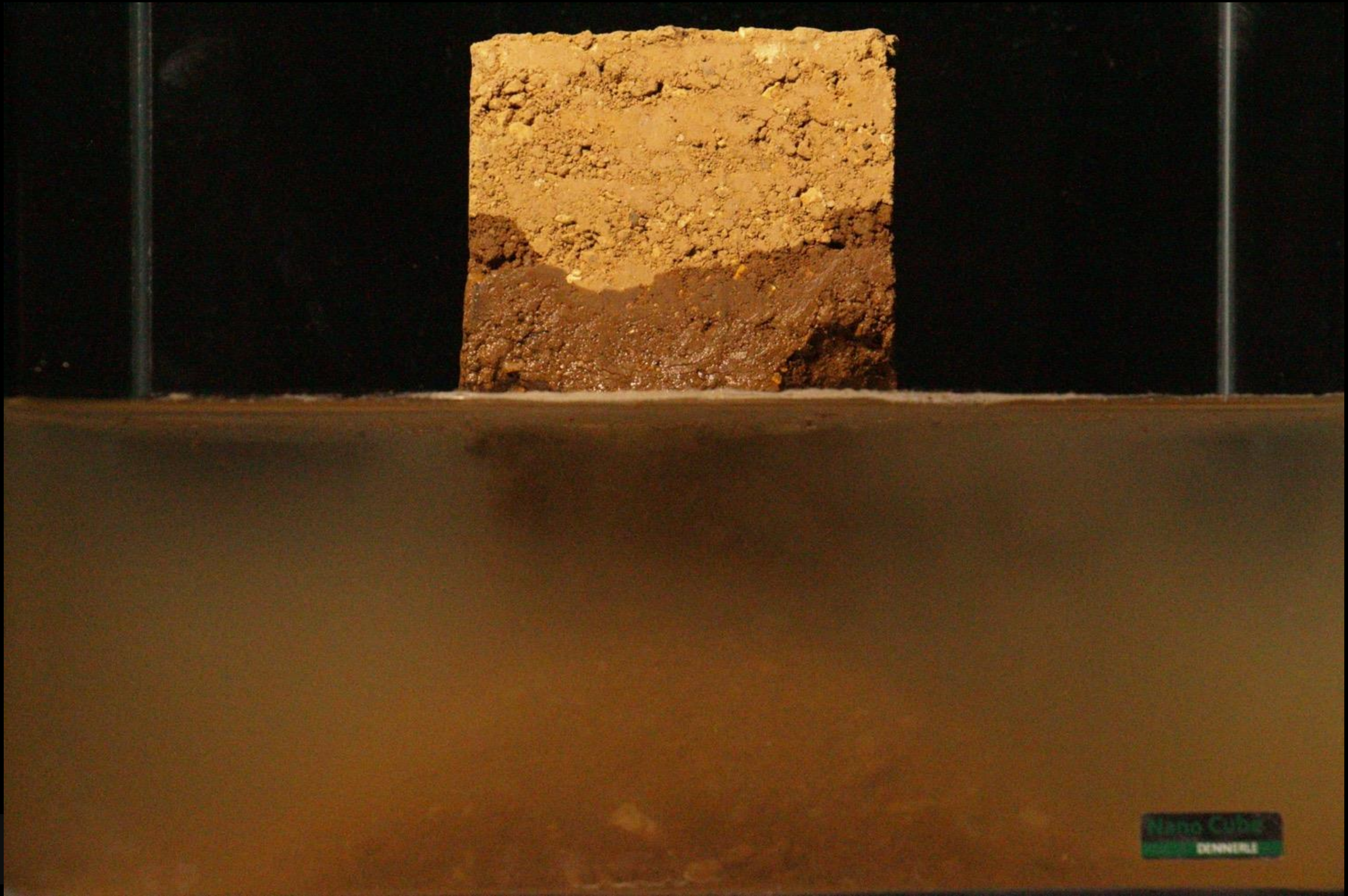
Positive and negative charges attracted
House of card structure which trap water inside


rammed earth
bricks
clay concrete
cement concrete
0
50
100
150
200
250
kgCO2 eq/m3
CHF/m3

Remaining challenges ?


Nano Cube
DENNERLE


Nano Cube
DENNERLE


Nano Cube
DENNERLE


Nano Cube
DENNERLE

Remaining challenge
Water resistance

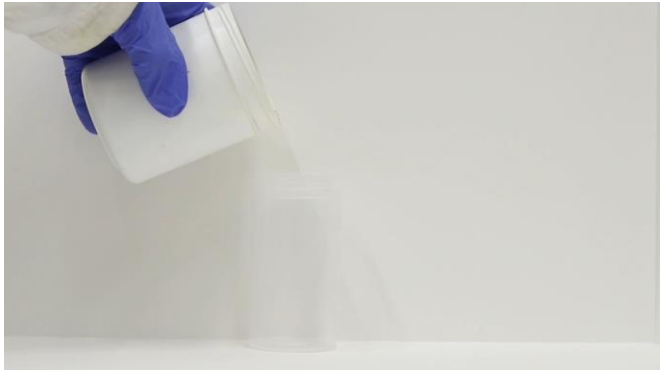
Vernacular strategy
Big hat & good boots

Natural waterproof substance
(egg albumin)

Waterproofing with natural materials

Remaining challenge
Water resistance

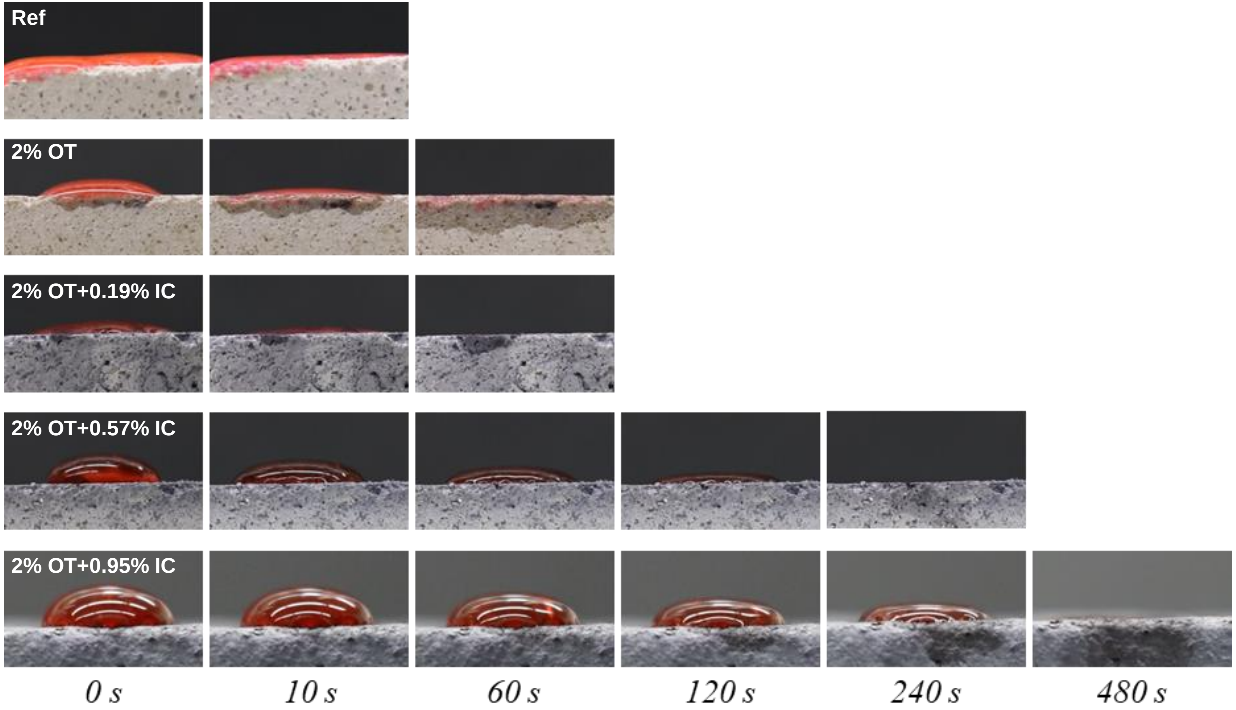
Tanins and iron oxide combination
Provide both poured earth technique possibility
And water resistance




Sce: Du et al. 2022. Design of Tannin-Based Poured Earth Material via Deflocculation–Coagulation Control: Additive Selection and Tannin Variation. *ACS Sustainable Chem. Eng*

Remaining challenge
Water resistance

Tanins and iron oxide combination
Provide both poured earth technique possibility
And water resistance



Du, Y., Habert, G., & Brumaud, C. (2022). Influence of tannin and iron ions on the water resistance of clay materials. Construction and Building Materials,

Remaining challenge
reinforcement

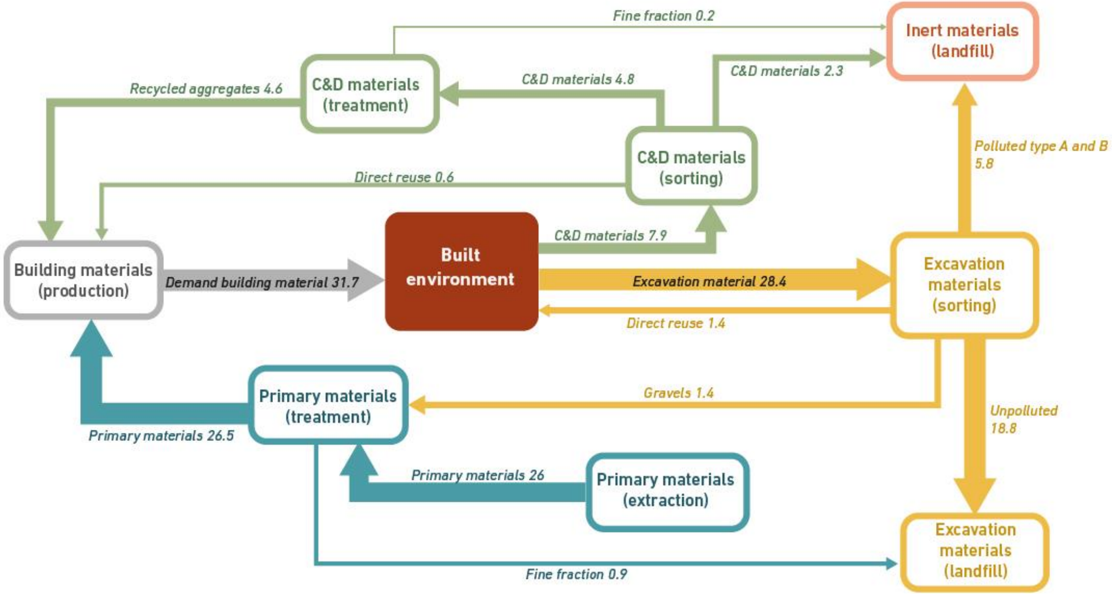
Post tensioned earth allows to go higher and thinner

Sce: Cham tower, Roger Bolthauser & LehmAG, Cham (Switzerland)

Remaining challenge
reinforcement

Post tensioned earth allows to produce slabs

Sce: Schloss Charlottenbuch bei Bez+Kock Architekten & ERNE AG, Berlin (Deutschland)



Sce: Material flow in Switzerland in 2018. Expressed in 10^6.m^3/yr (KAR Model 2018, Adapted from Rübli, 2020)

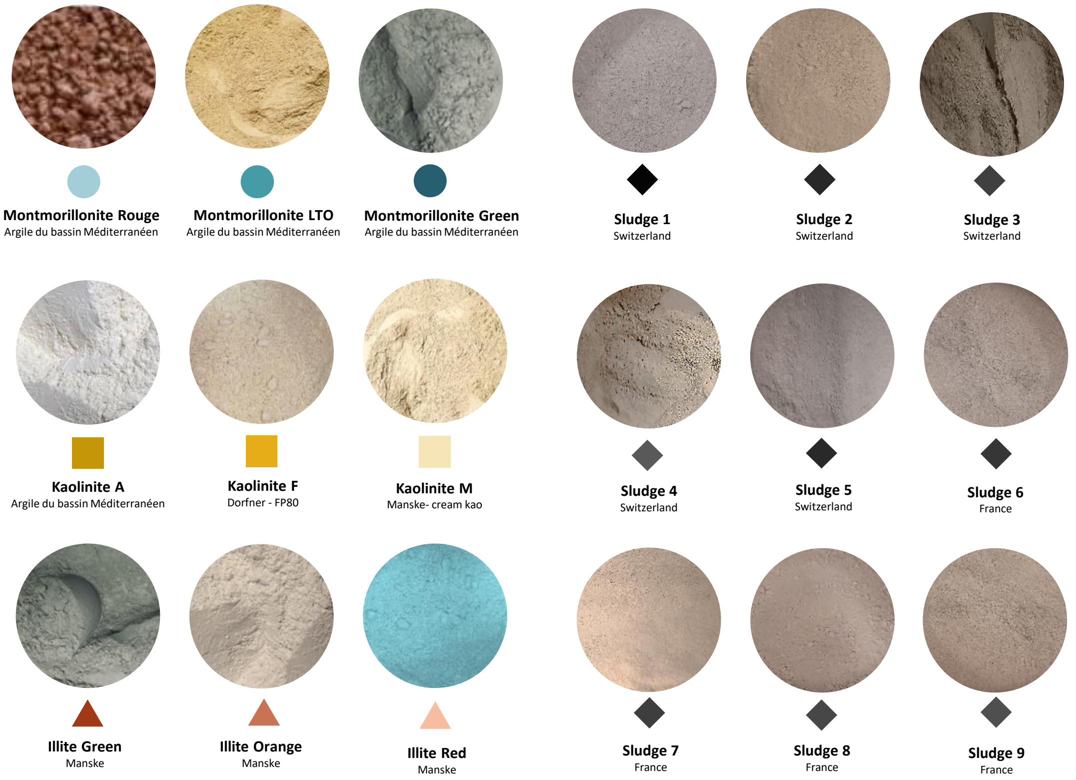
Remaining challenge
Variability

Excavated earth from Paris underground. amàco for Cycle Terre project. 2019

Remaining challenge
Variability

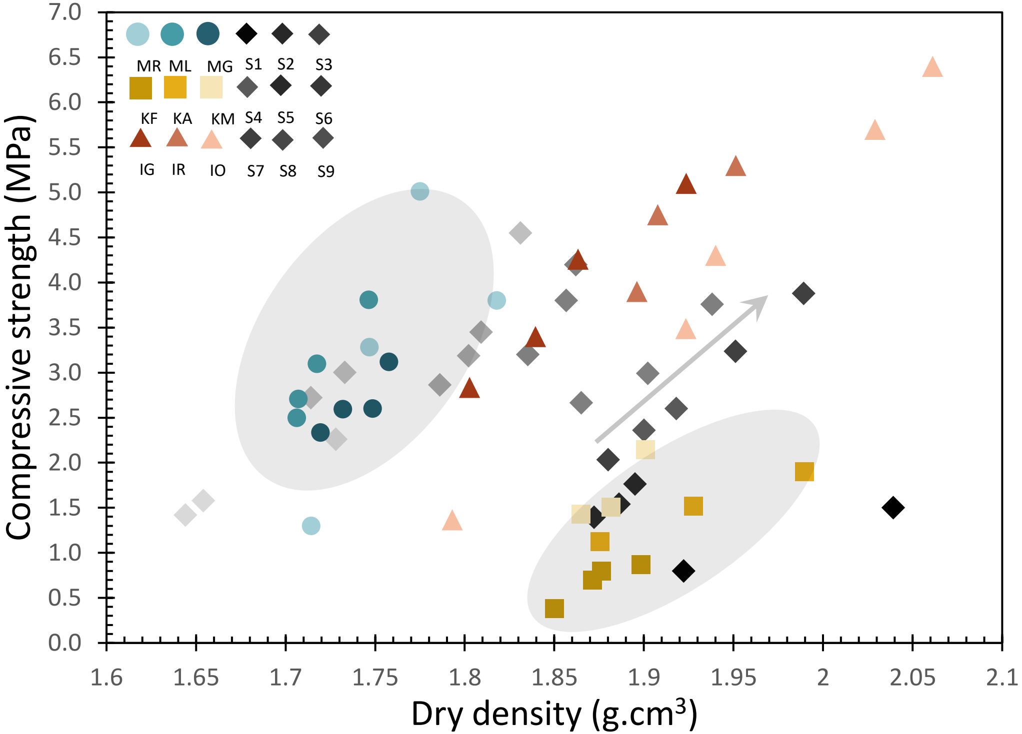
3 earth, same initial consistency, same amount of additive… very different results

Materials



Name	Relative density	Methylen blue value	Liquidity Limit
MG	2.422	32	126
ML	2.358	21	108
MR	2.464	22	93.95
KA	2.596	2.33	57.71
KF	2.54	1.66	62.3
KM	2.62	1.33	49.44
IG	2.43	11.66	83.5
IO	2.708	3.66	41.5
IR	2.718	3.33	40.47
S1	2.666	0.5	41.39
S2	2.630	1.66	32.5
S3	2.613	7	51.9
S4	2.612	1	38.28
S5	2.619	3.33	45.98
S6	2.644	1.33	40.80
S7	ND	0.7	36.5
S8	ND	1.83	46.2
S9	2.65	0.19	32

Results – *Impact of the dry density*



Compressive strength as a function of the dry density for all studied mixes.

Figure modified from Ardant et al., Robust clay binder for earth-based concrete, CCR, 172, 2023

Conclusion

Opportunities

Ressource widely abundant
Low CO_2 and fully circular
Uses same know-how and infrastructure as concrete *(except reinforcement)*

Challenges

Low strength forces to design differently *(wood-earth composite or thicker walls)*
Absence of internal reinforcement requires careful design *(ring beam or post tension)*
Low water resistance forces to design differently *(protect)* **or to use different additives** *(biostabilization)*
High variability of earth is the main challenge to widespread the technology

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Thank you for your attention

Prof. Dr. Guillaume Habert
Chair of Sustainable Construction