The compressive strength of earth-hemp blocks tested with different densities, earth types, and cementitious binders

Douillet, G. A.[1], Toropovs, N.[2], Zucha, W. J.[3], Bernard, E.[2], Kühnis, A.[1], and Schlunegger, F.[1]

guilhem.douillet@geo.unibe.ch

UNIVERSITÄT BERN

Empa
Materials Science and Technology

ETH zürich

Starting as a customer...

Insulated of a timber-framed house:

+ No structural need (timber-frame support)
+ Need good hygroscopic properties
+ Minimize environmental cost
+ As light as possible for better insulation

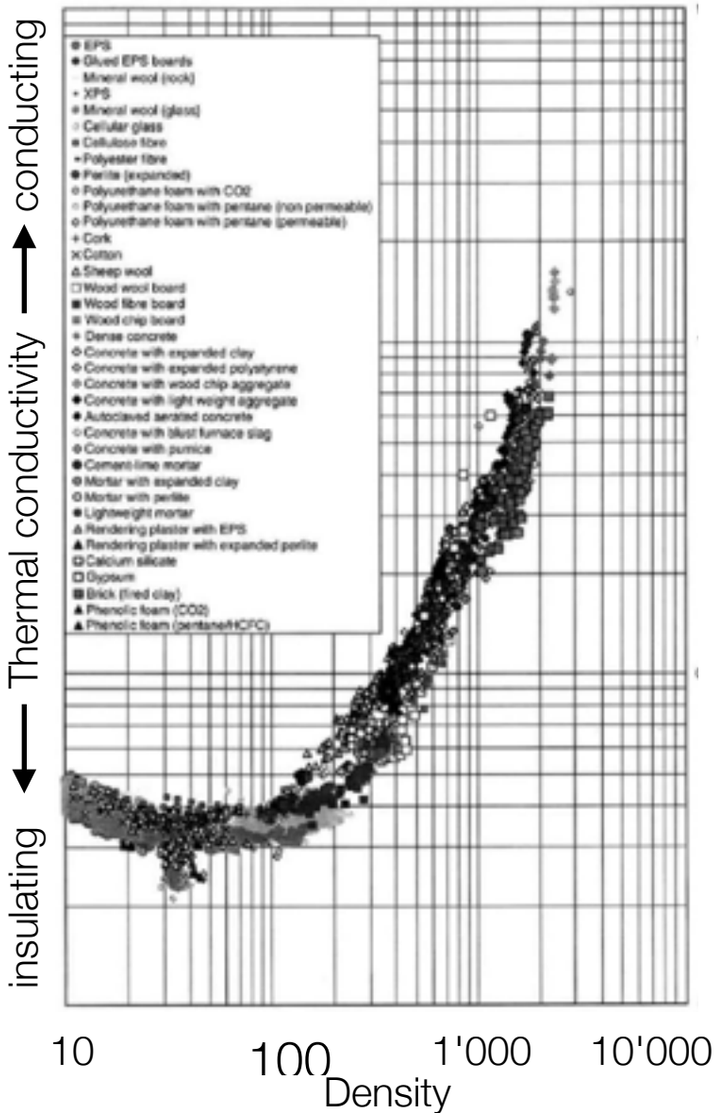
+ RAW EARTH

~ 0 kg CO2 / ton

=> "Hempcrete":

Hemp aggregates + ~~Binder of Lime and/or Cement~~

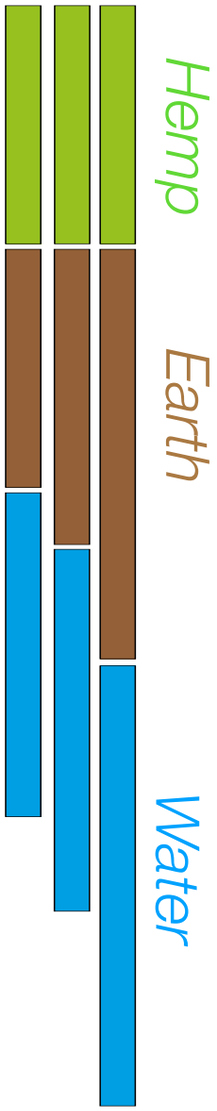
1900 kg CO2 / ton ~~+500-900 kg CO2 / ton~~

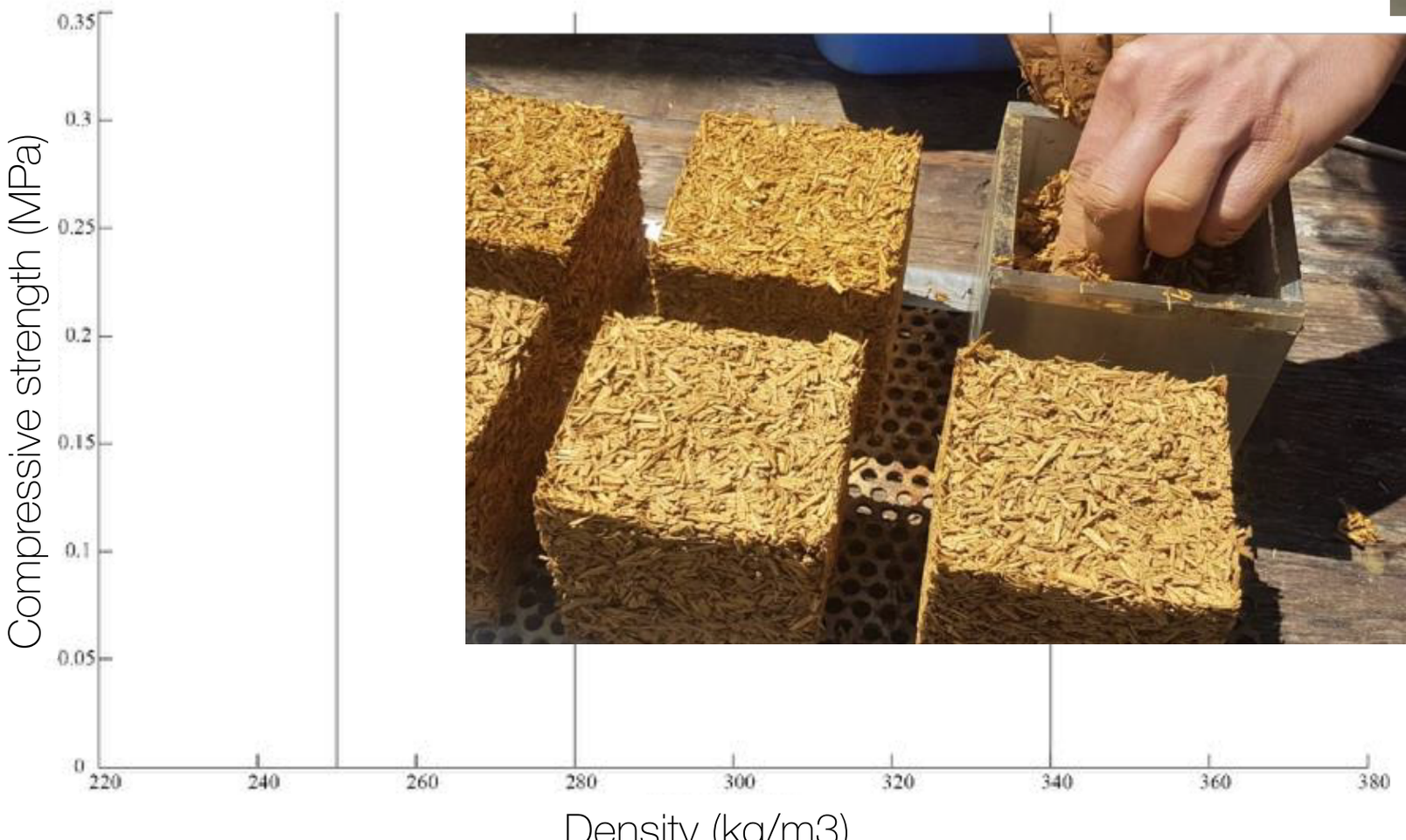


Earth Hemp Blocks...

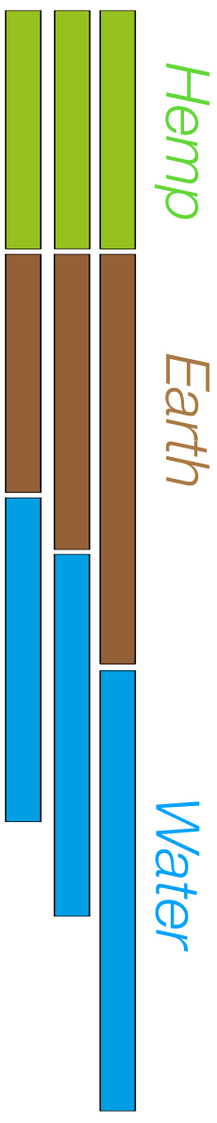
Target densities:

250 kg/m3
280 kg/m3
340 kg/m3

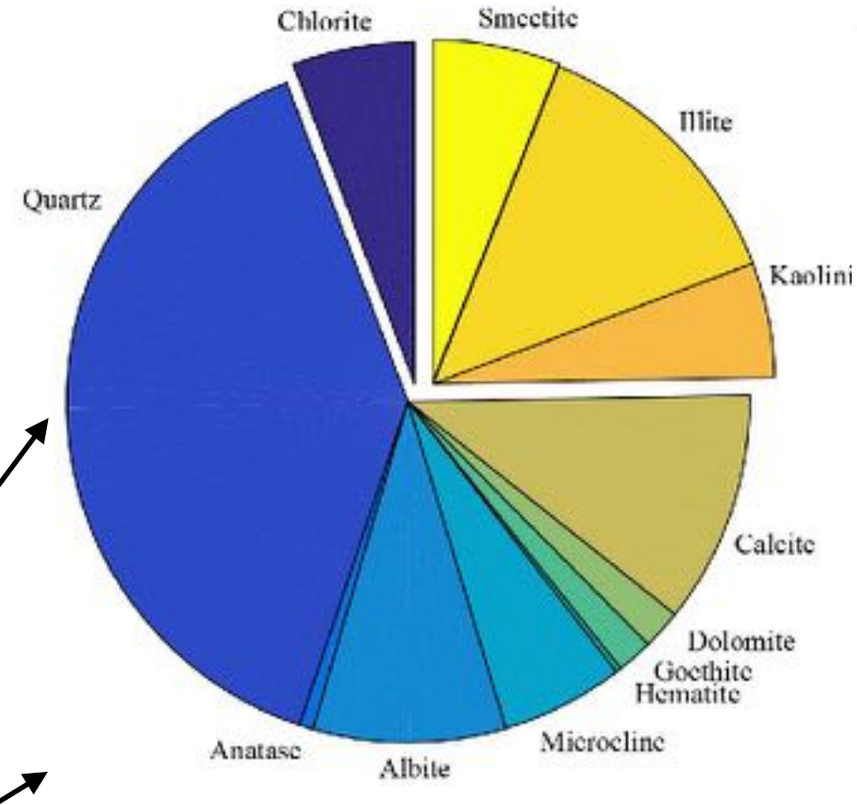




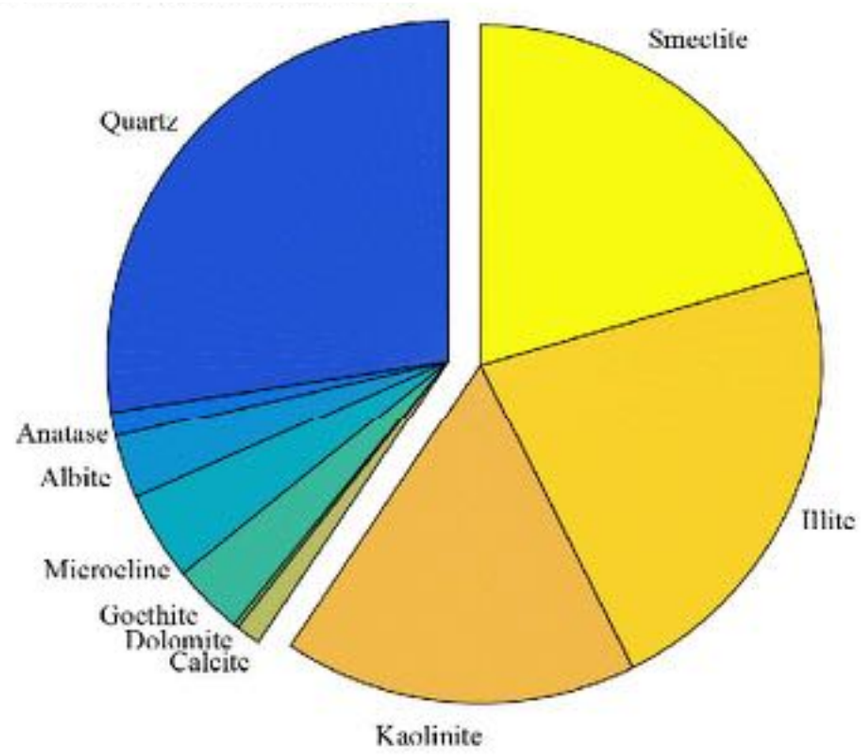
Influence of earth type

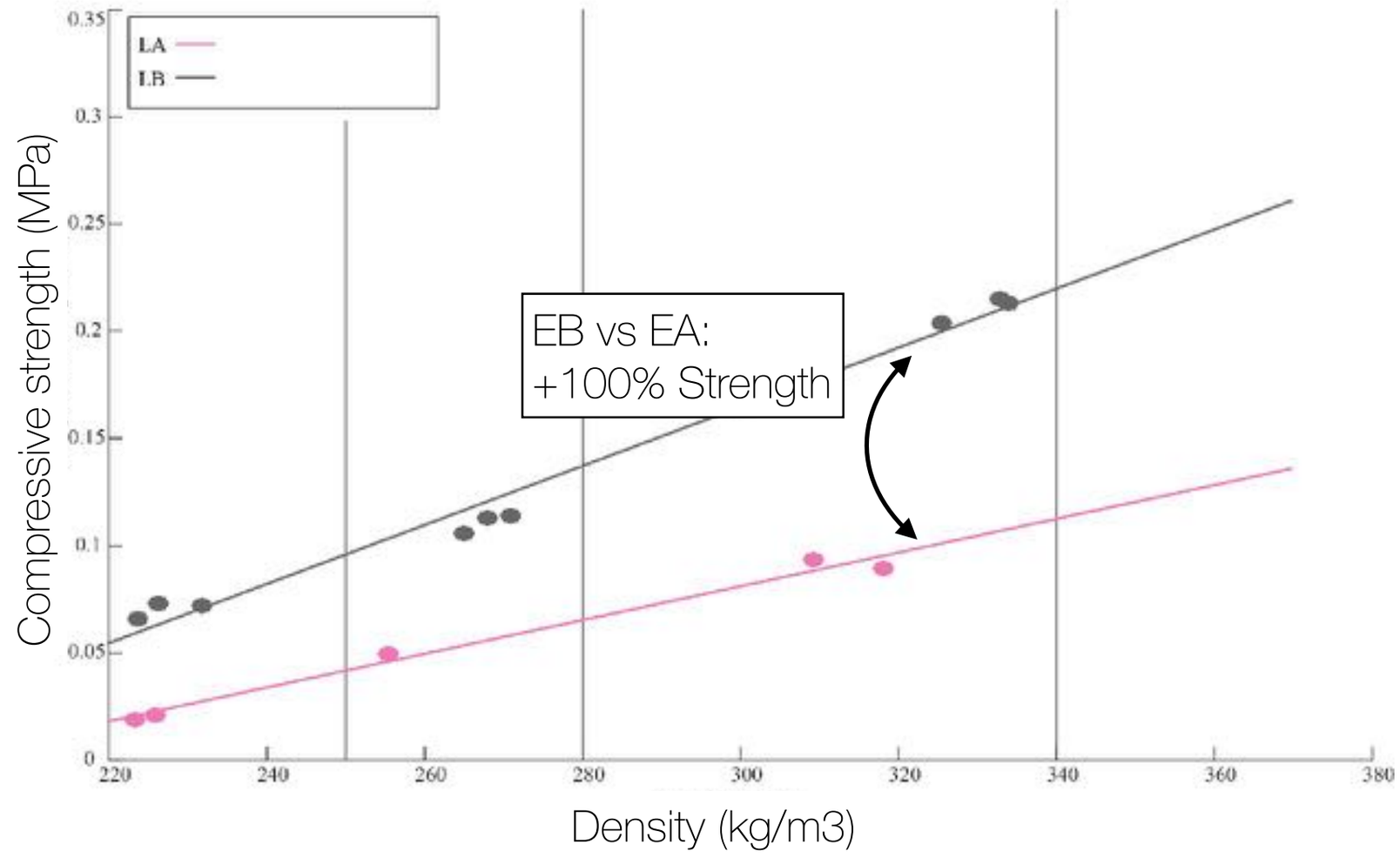


Earth A: 25 % clay minerals

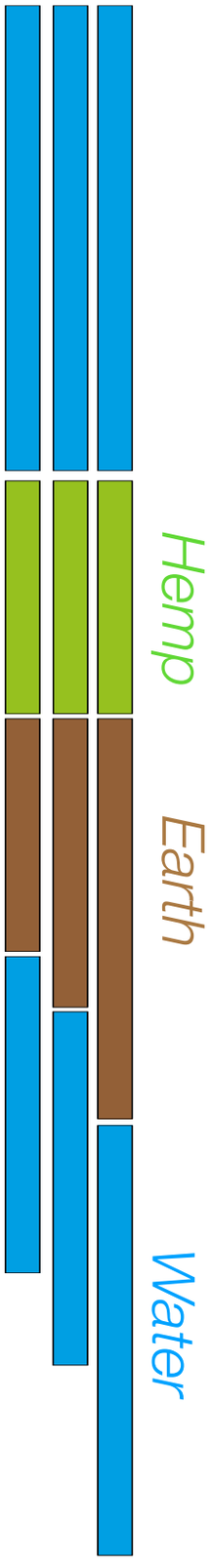


Earth B: 61% clay minerals

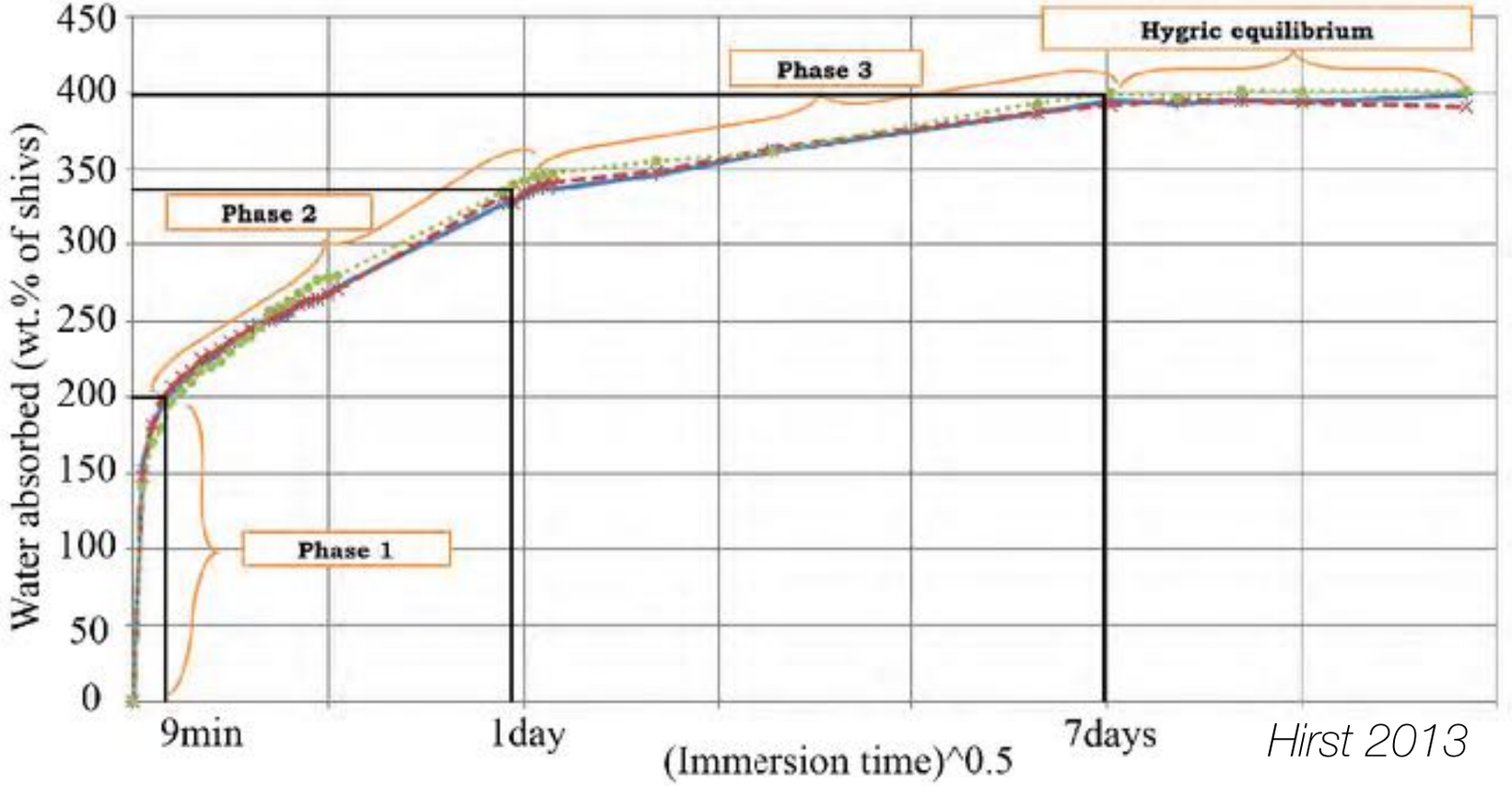




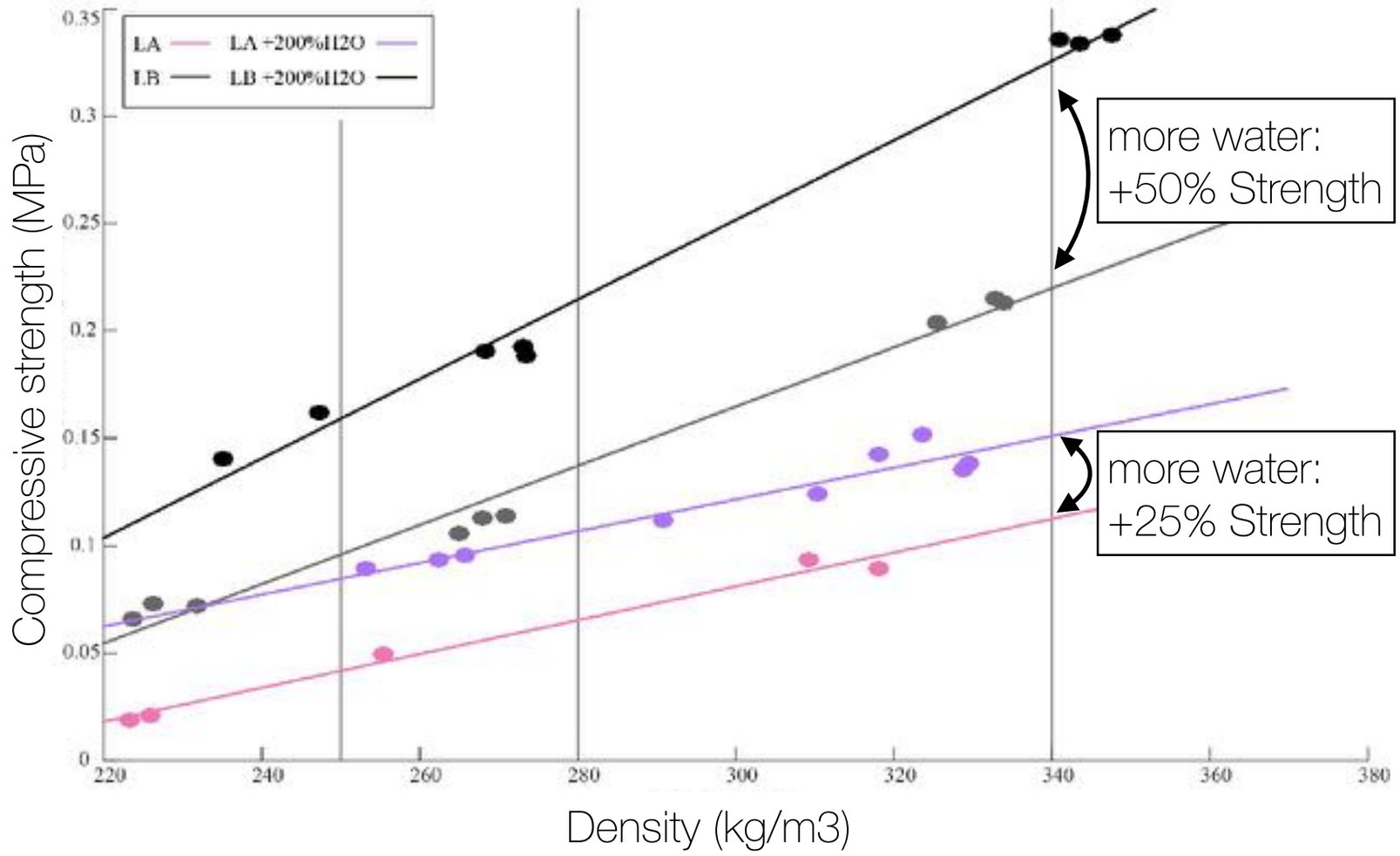
Influence of water



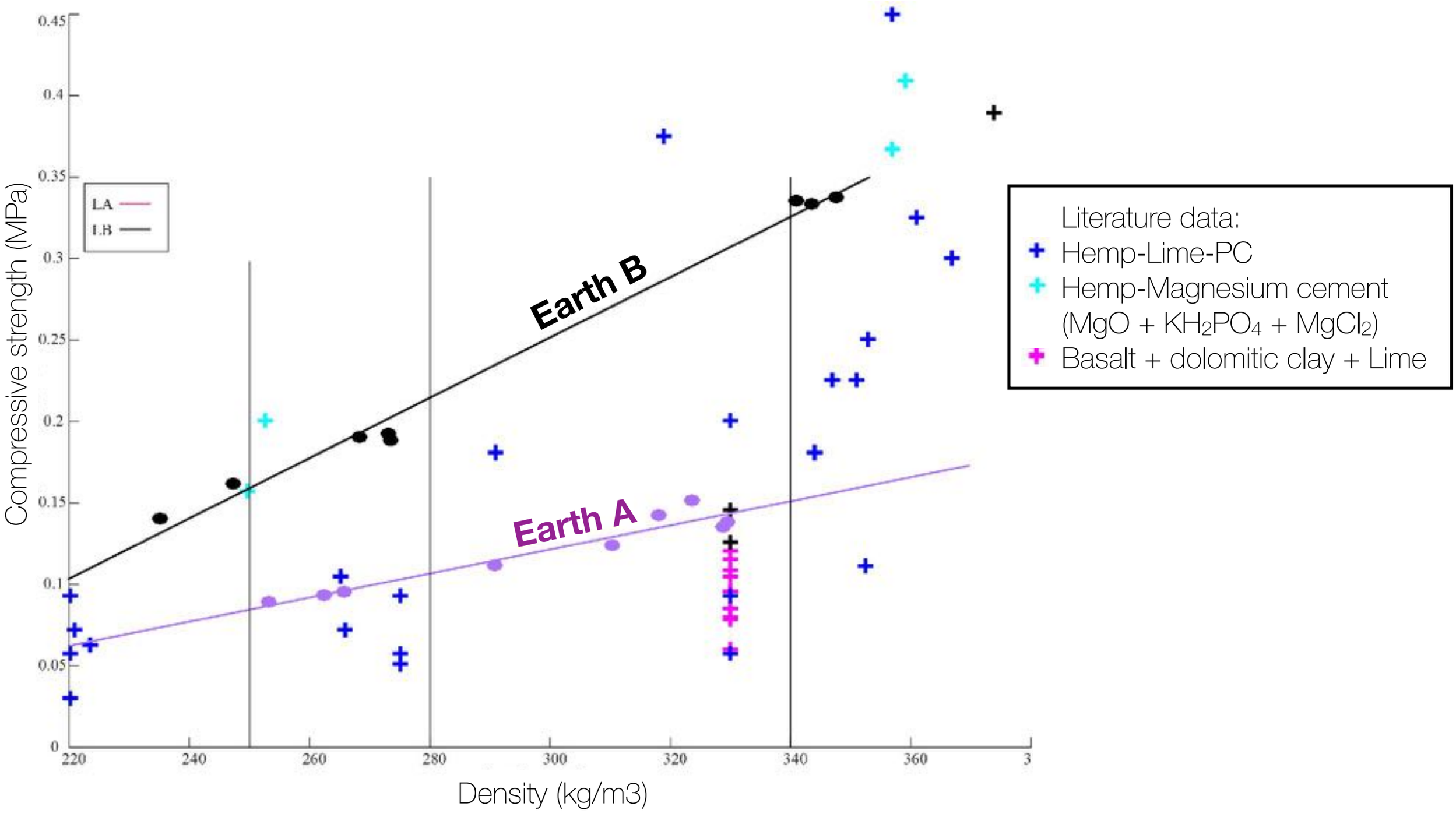
+200wt.% water soaked in hemp



Hirst 2013



Earth-hemp can be stronger than most hempcretes

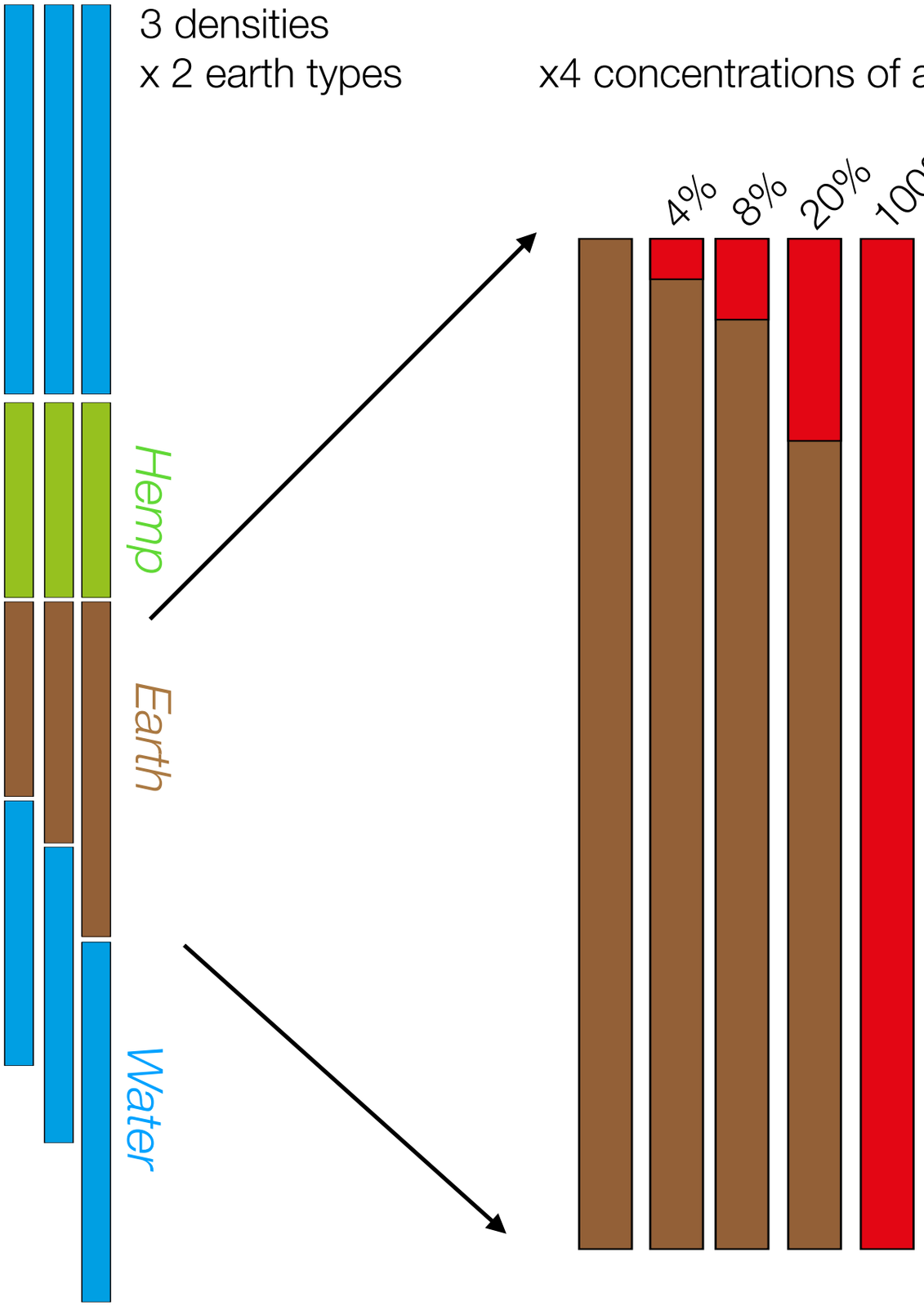


Additives for stabilization...

3 densities
x 2 earth types

x4 concentrations of additives

x 4 types of additives



Magnesium cement
MgO + reactive clay + NaHCO3

Hydrated lime
Ca(OH)2

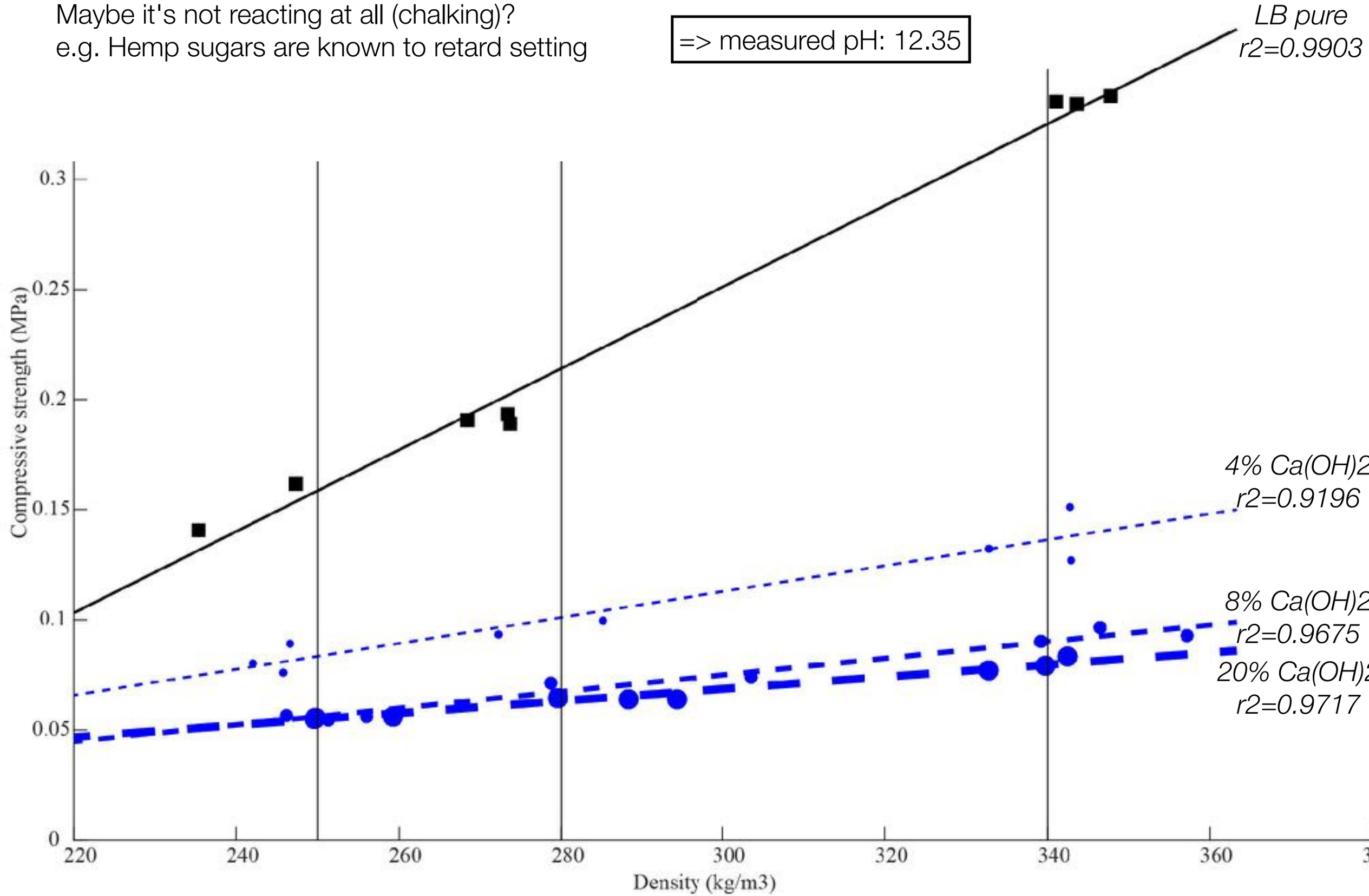
Portland Cement
CEM I

Calcined Gypsum (Plaster of Paris)
CaSO4

Stabilizing: hydrated lime

Maybe it's not reacting at all (chalking)?
e.g. Hemp sugars are known to retard setting

=> measured pH: 12.35

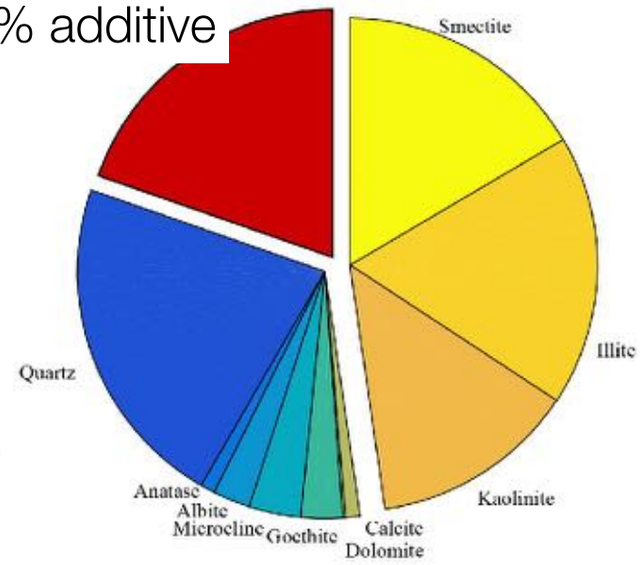


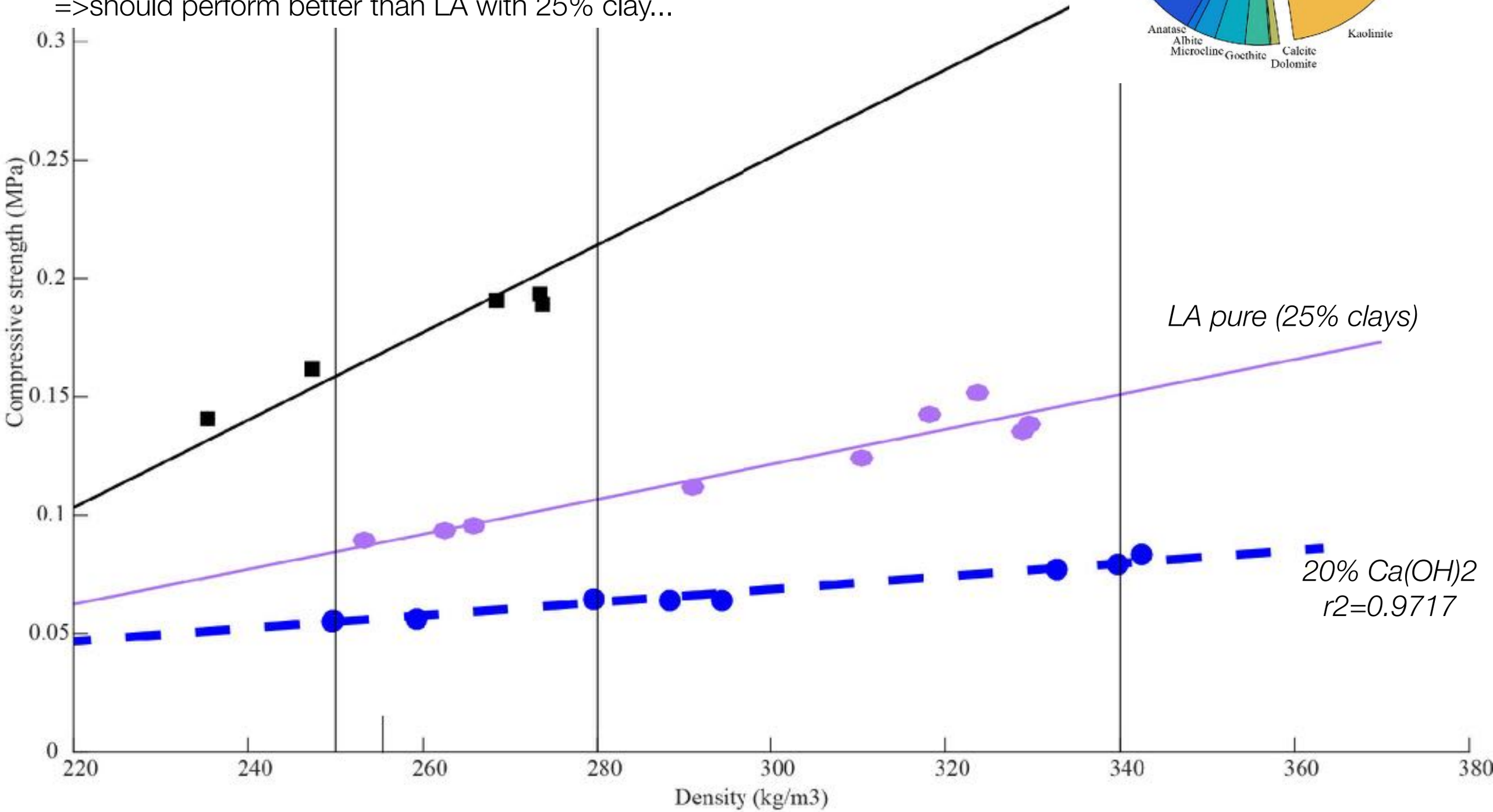
Stabilizing: hydrated lime

Maybe it's not reacting at all (chalking)?
e.g. Hemp sugars are known to retard setting

=> measured pH: 12.35

If the lime was simply "passive", there would still be 50% clay,
=>should perform better than LA with 25% clay...



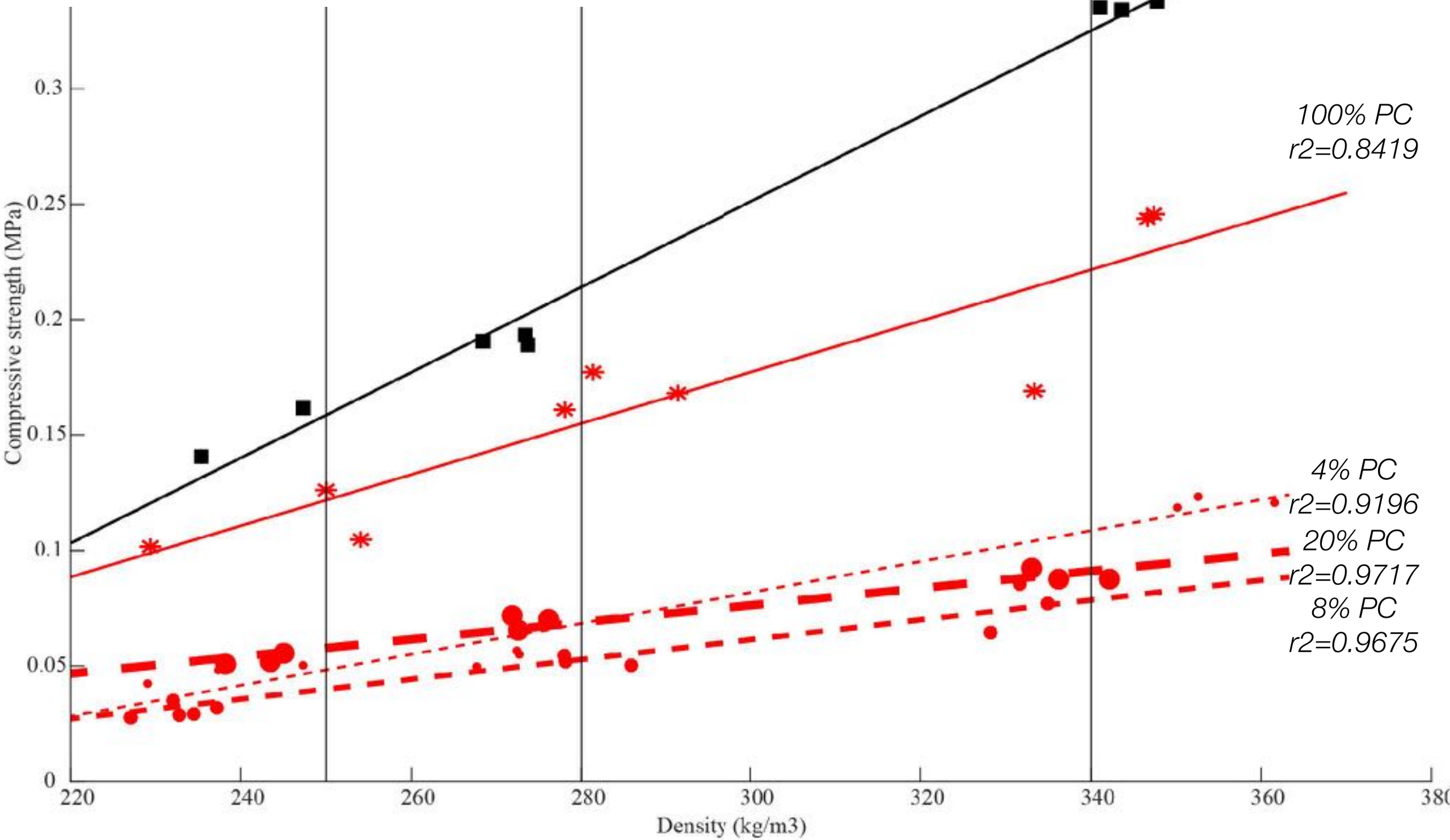


Stabilizing: Portland cement

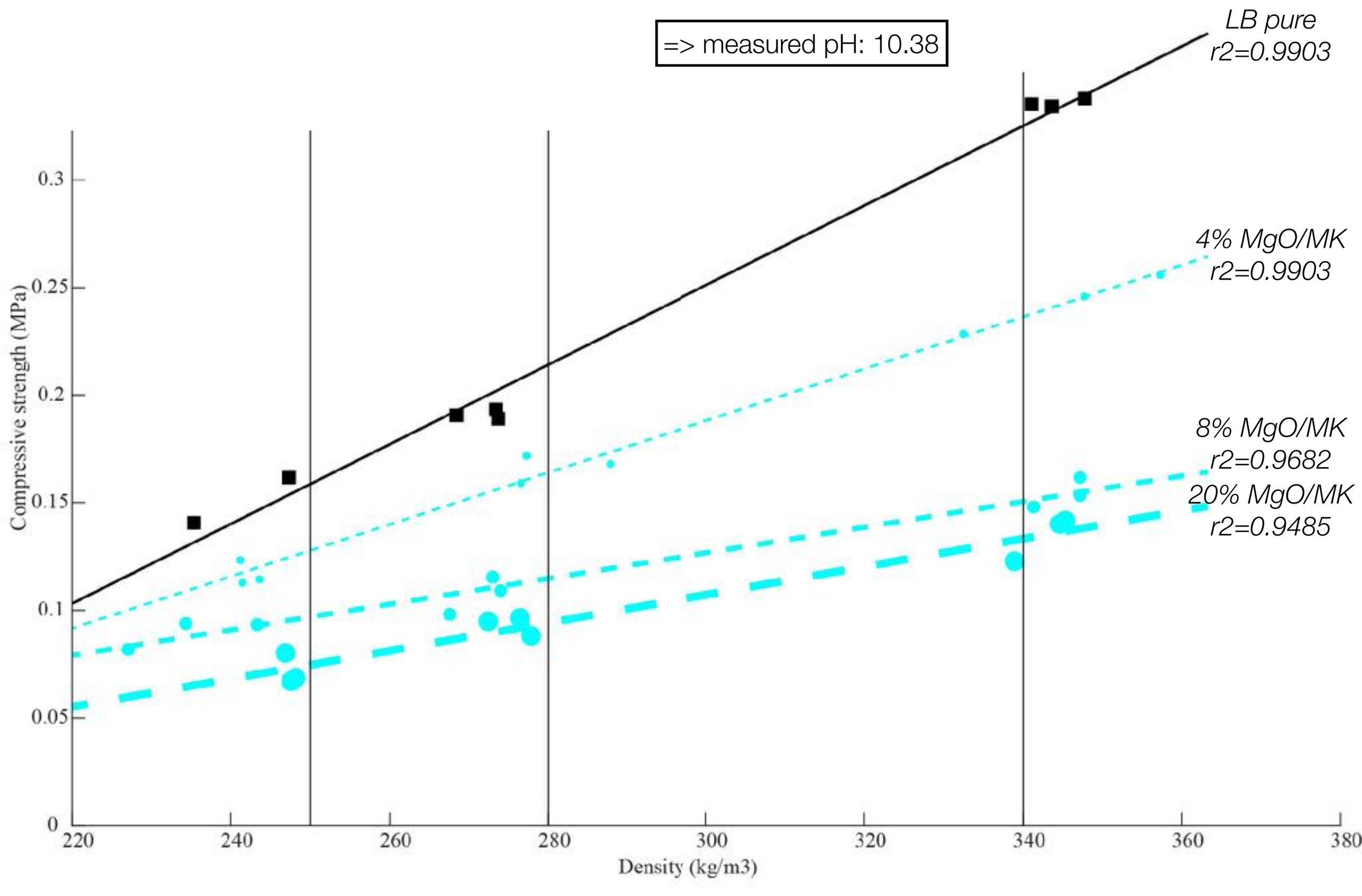
Maybe the pH hurts the hemp?

Then 100% PC should be the worse...

=> measured pH: 12.54



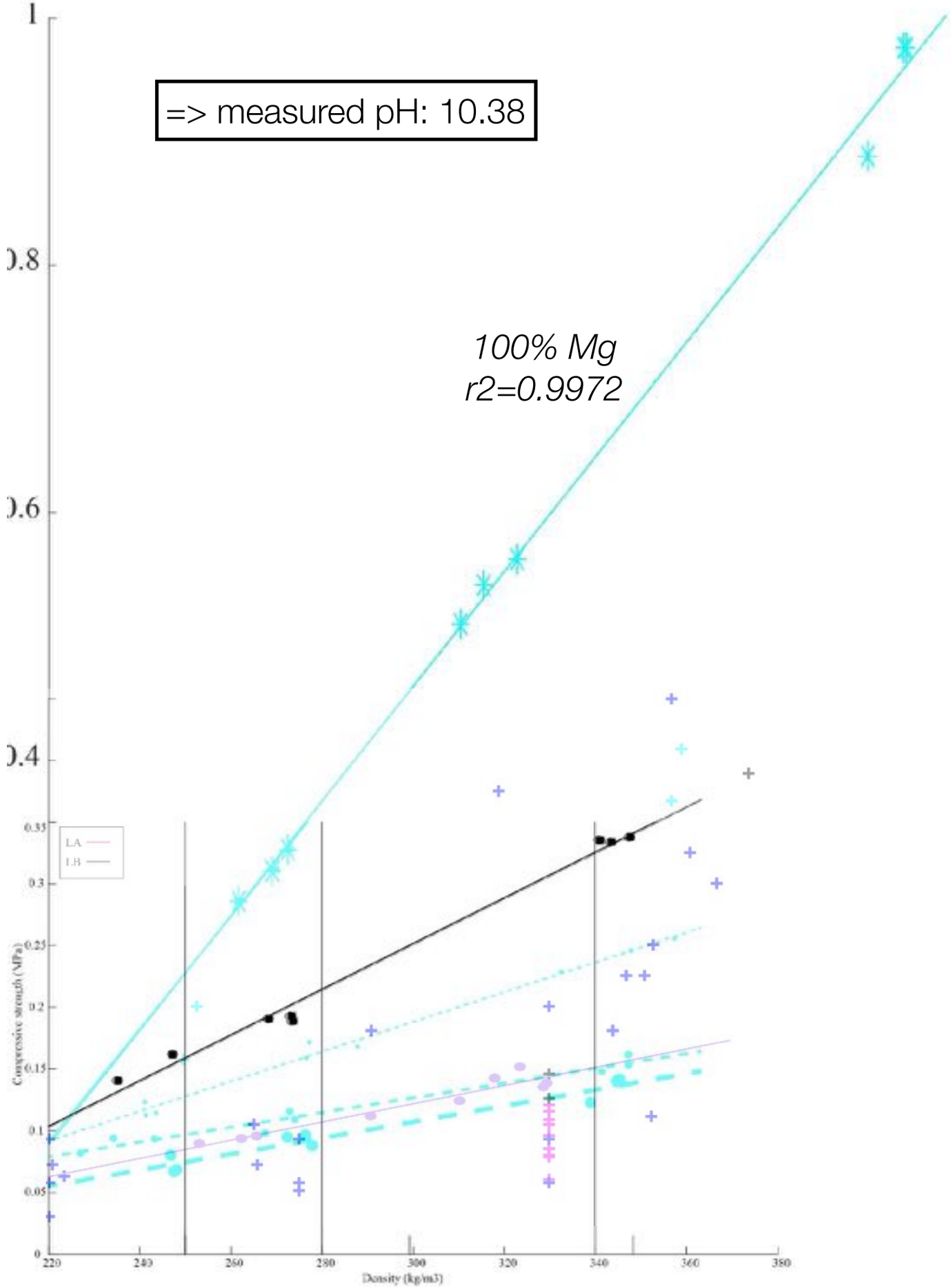
Stabilizing: Mg-based



Stabilizing: Mg-based

Pure Mg-based binder actually performs better than any published hempcrete...

=> measured pH: 10.38



Stabilizing: calcined gypsum

=> measured pH: 6.9

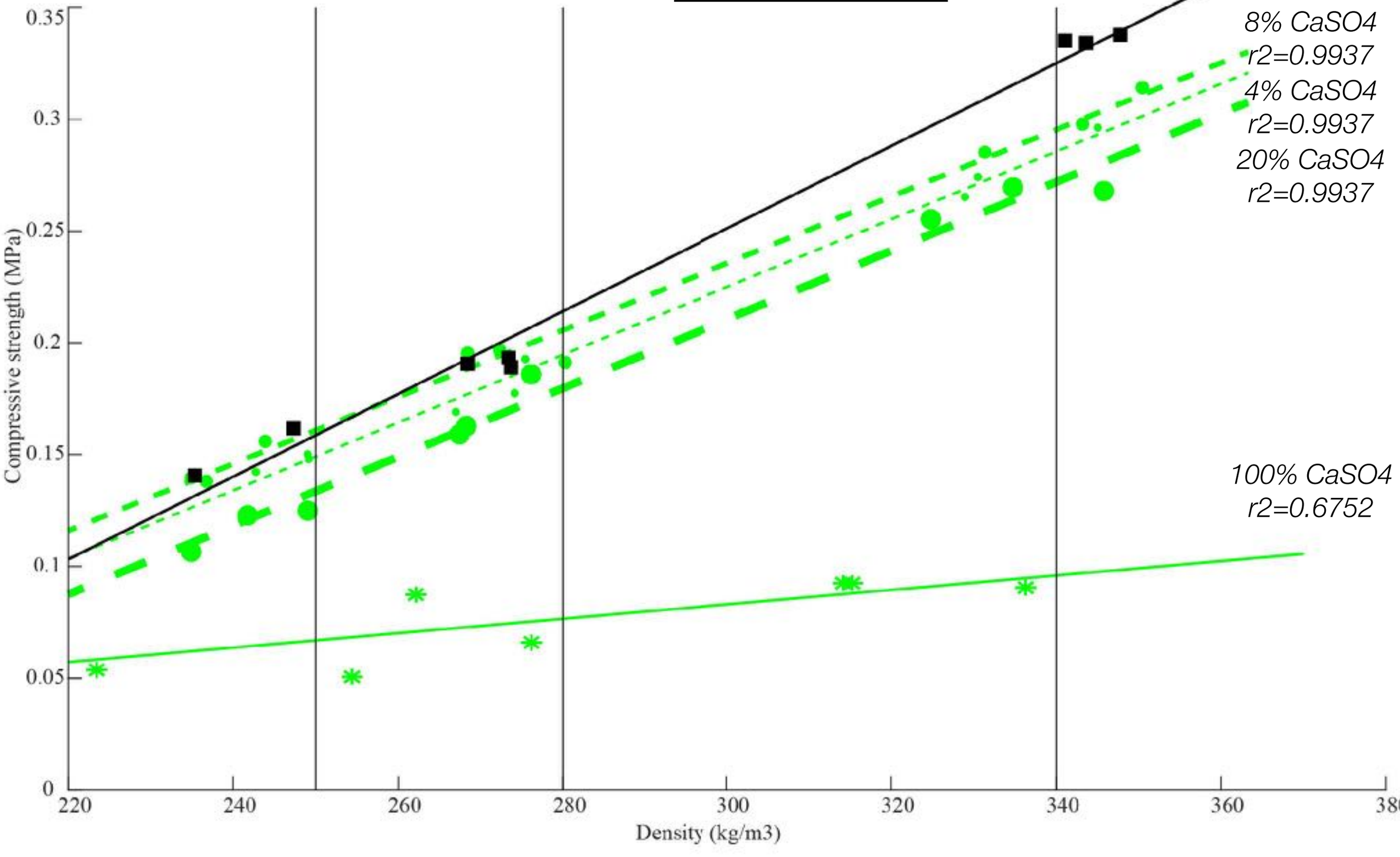
LB pure
r2=0.9903

8% CaSO4
r2=0.9937

4% CaSO4
r2=0.9937

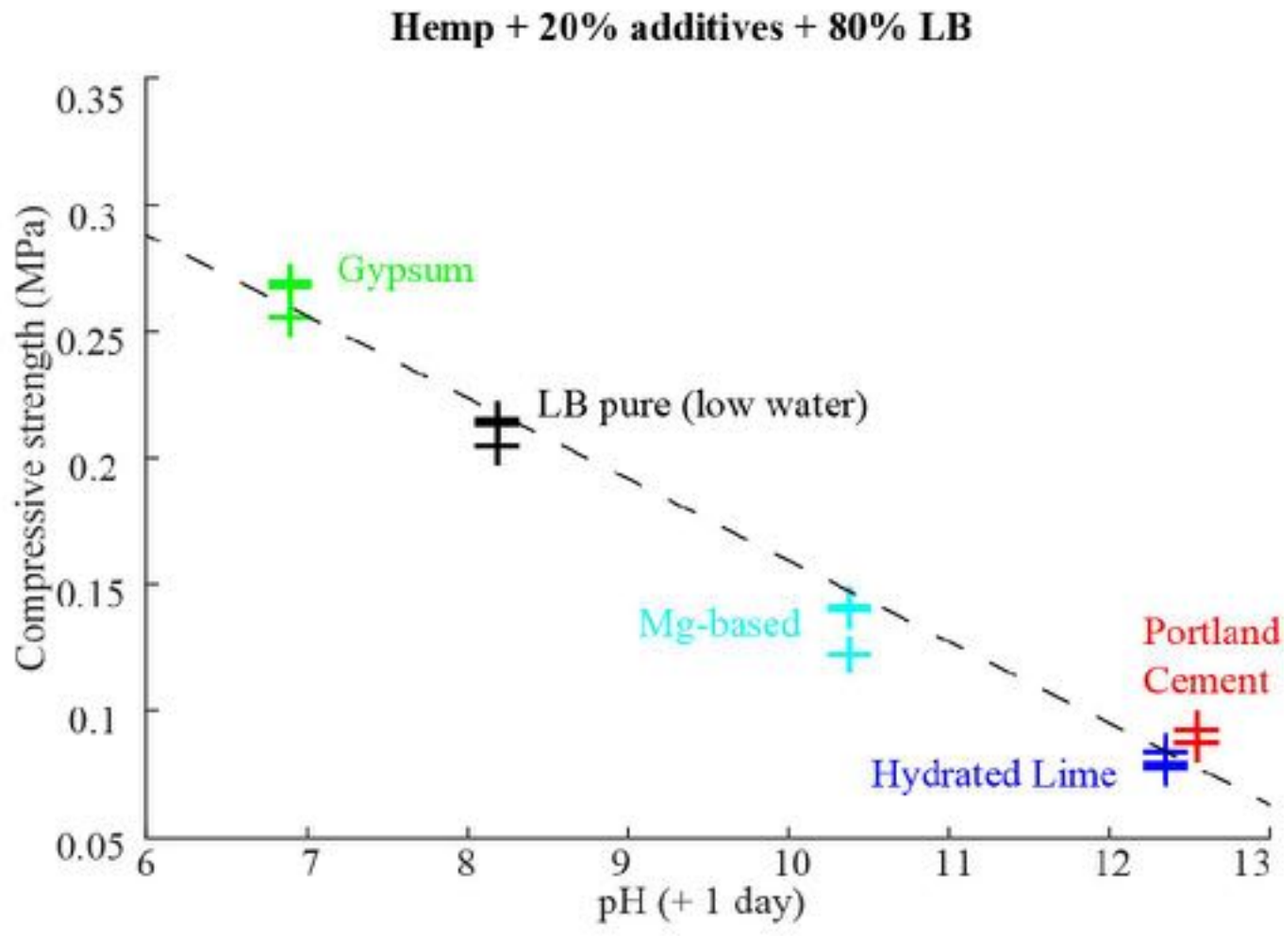
20% CaSO4
r2=0.9937

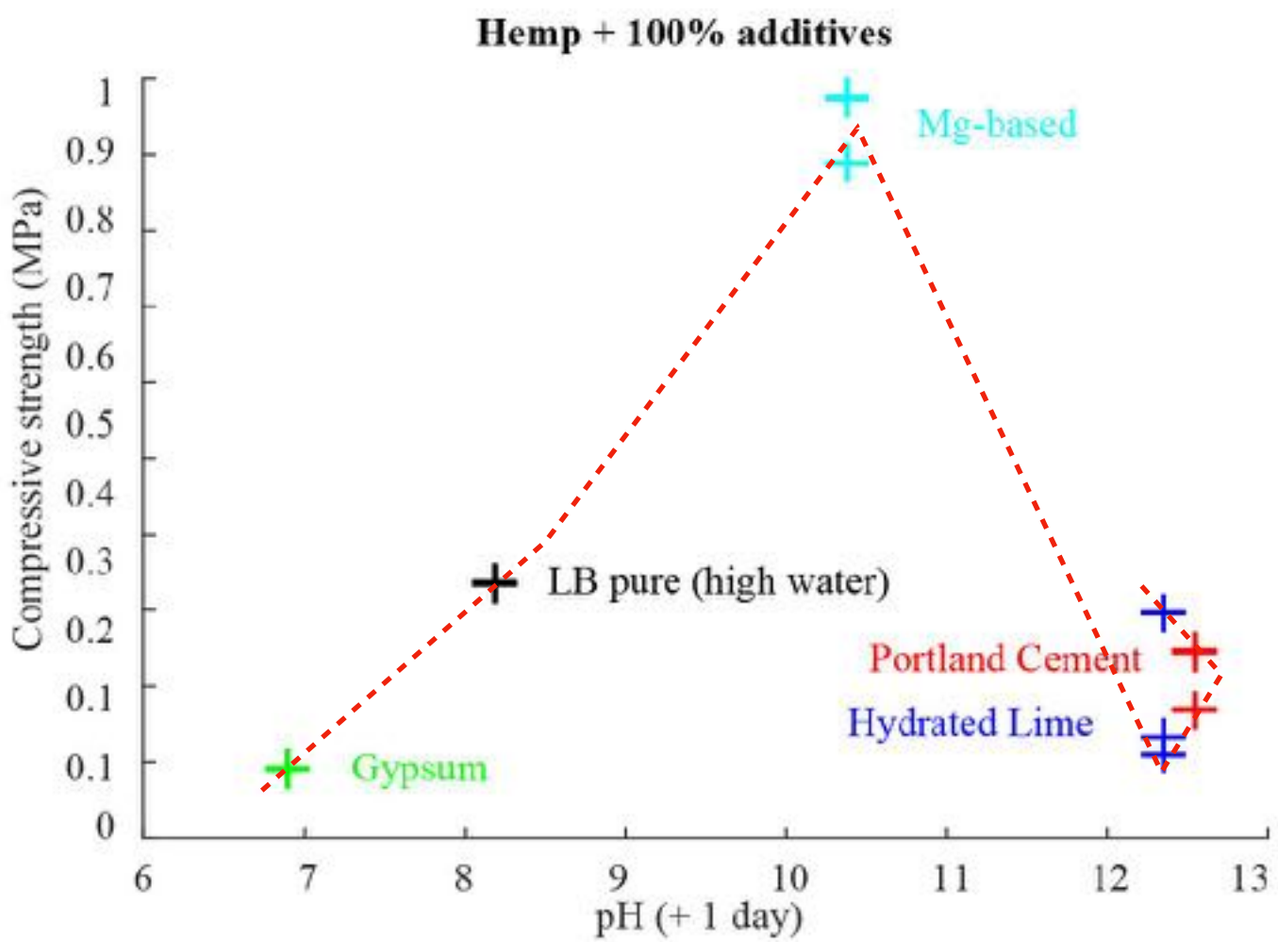
100% CaSO4
r2=0.6752



There is a link with pH...

...but only in the presence of clays and hemp





A possible explanation:
-In alcaline conditions, pectins (Galacturonic acid) may get ionized and basic forms predominate.
-In that state, the hemp surface may become charged negatively, which may hinders the contact with clays that are also predominantly charged negatively.

Conclusions

-Lightweight Earth-hemp is stronger than most hempcretes provided:
High content in clay minerals + High amount of water

-Linear correlation between density and compressive strength (r2 avg.=0.97, min=0.92, max=0.99).

-Cementitious additives are destabilizing
-Compressive strength related to pH, (in the presence of clay and hemp)
=> Hemp surface (pectins) get charged negatively in alcaline solution, hindering contact with clays (predominantly charged negatively).

guilhem.douillet@geo.unibe.ch

Realisations

2019-2020: (First test in a full scale house)

25 cm plastering on ancient straw-earth mix
3 days work with 3 people
31m3 of earth hemp (125m2 wall)
7 tons CO2 sequestered
8'000€

Realisations

2021: customer K. Reinhard (Wentzwiller, France)

Entire wall thickness with earth-hemp (25 cm)
3 days work with 3 people
36m3 of earth hemp
8.2 tons CO_2 sequestered
10'000€ (36m3 of earth hemp)
R~3.7 (m2.K)/W; U~0.27 W/(m2.K)

The spraying method

Up to 2m3 / hour sprayed.
Several weeks/months drying time of the wall
Limited to Loess type earth (below 30% clay minerals)

The dry blocks method

Dry blocks, ready to use.
60*30*10 cm
Can be made with any type of earth (very light with high clay content)