Engineered Living Building Material (LBM) by Binder-jetting on Mars

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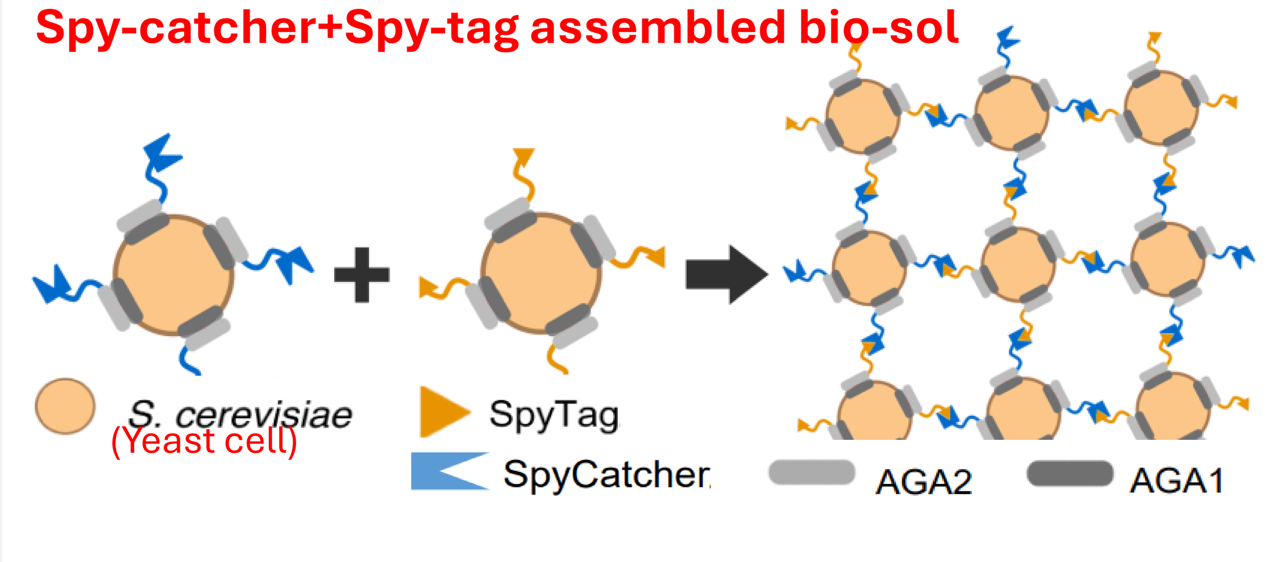
1.Raw Material

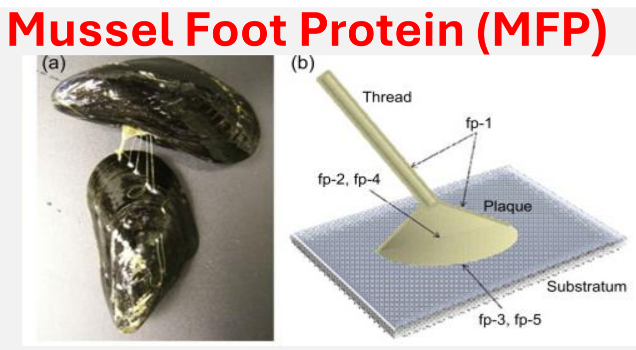
-Biosynthetic adhesive hydrosol

- Previously, we use Gelatin(artificial) to make LBM
- **Here, Genetic Engineered Yeast** to display ultra strong adhesive proteins on surface
- Cell assembly into bio-sol
- **Strong intercellular interaction**
  - SpyTag+SpyCatcher (A+B)
- **Strong adhesion to substrate**
  - Mussel Foot Protein (MFP)
  - Collagen

Spy-catcher+Spy-tag assembled bio-sol



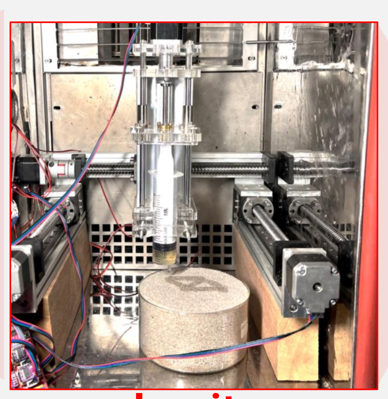
Mussel Foot Protein (MFP)



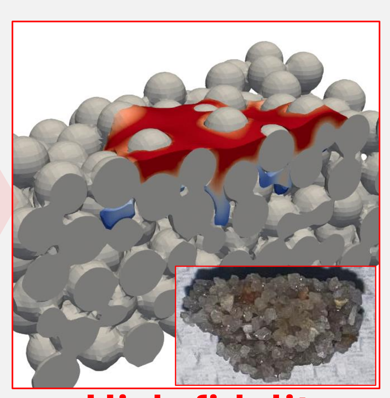
Collagen

2. Manufacturing

-Binder jetting of LBM/Bio-LBM



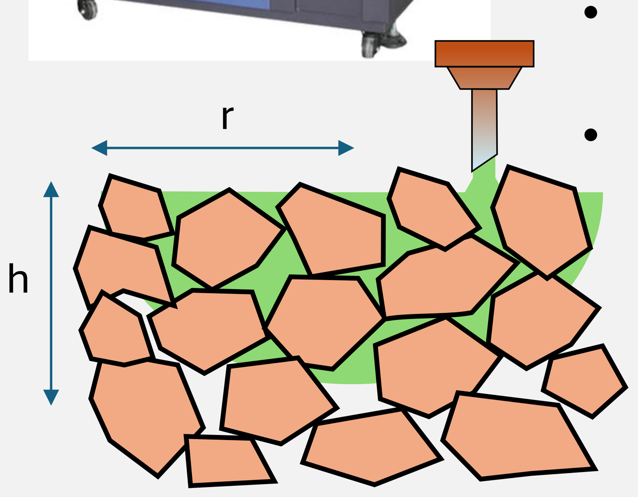
In-situ binder jet test



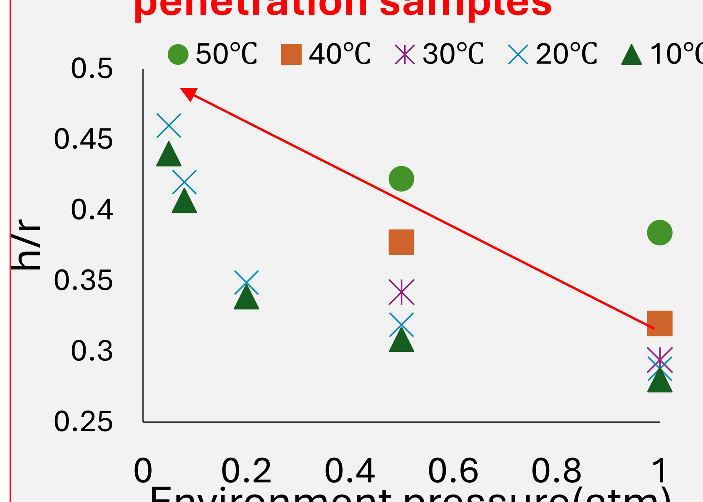
High-fidelity CFD-DEM model

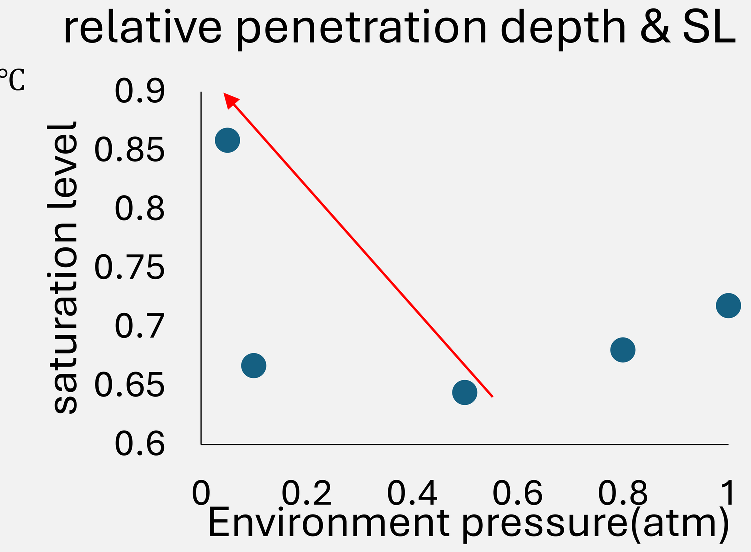
Low T, P

- 3d printing by hydrogsol binder jetting in low pressure conditions
- Single droplets penetration test
  - **Penetration depth &width**: control printing accuracy
  - **Saturation level**: control mechanical strength of green part
- Lower pressure has higher relative penetration depth & SL



Geometric of single droplet penetration samples

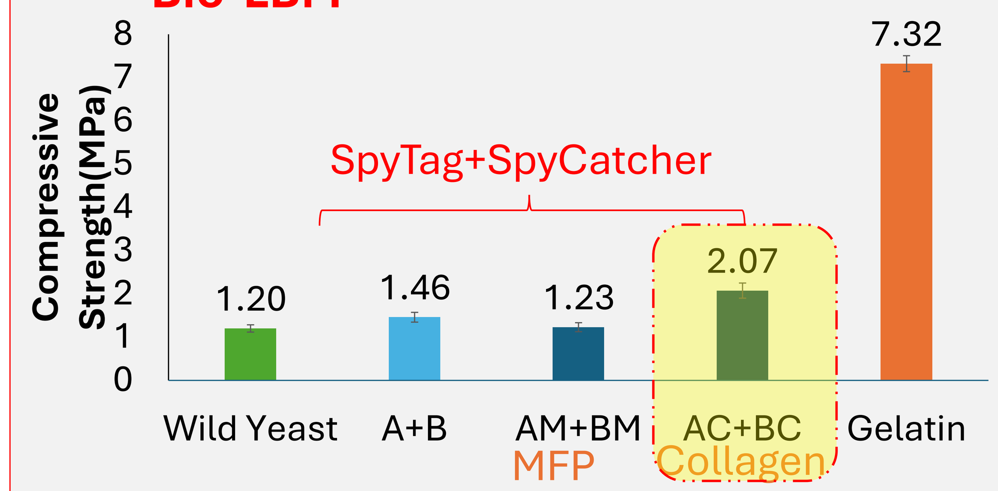




5. Material Properties $ Microstructures

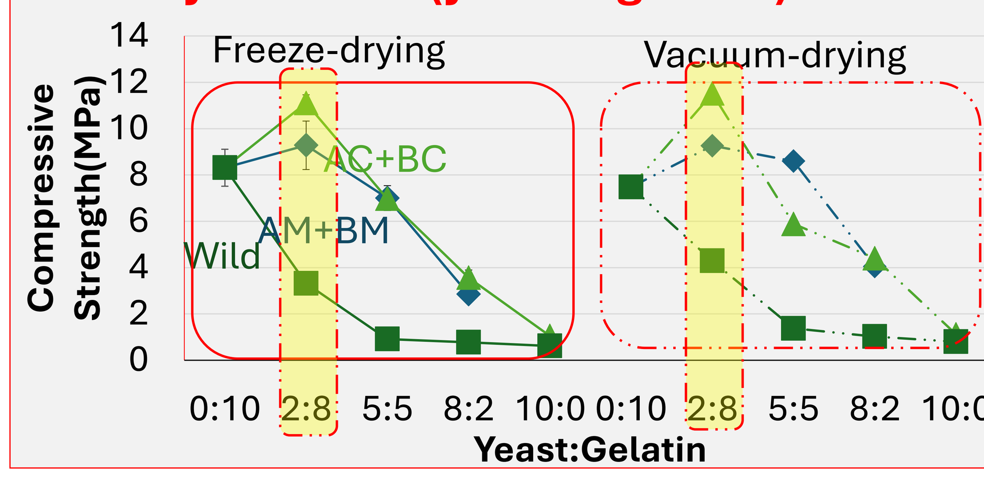
-Mechanical strength

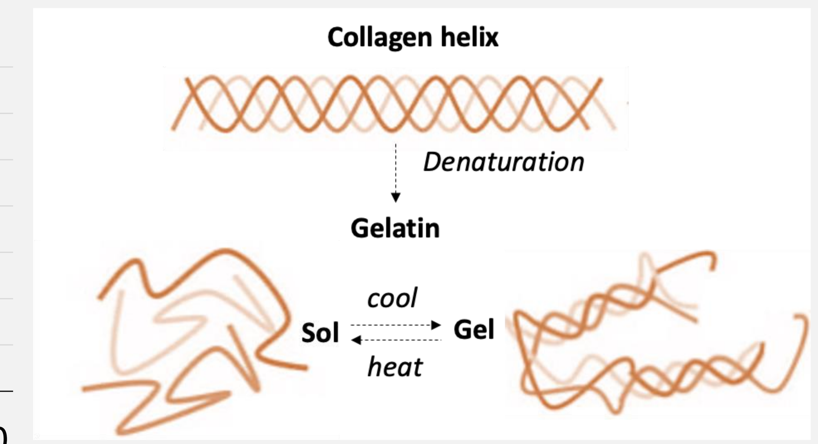
Bio-LBM



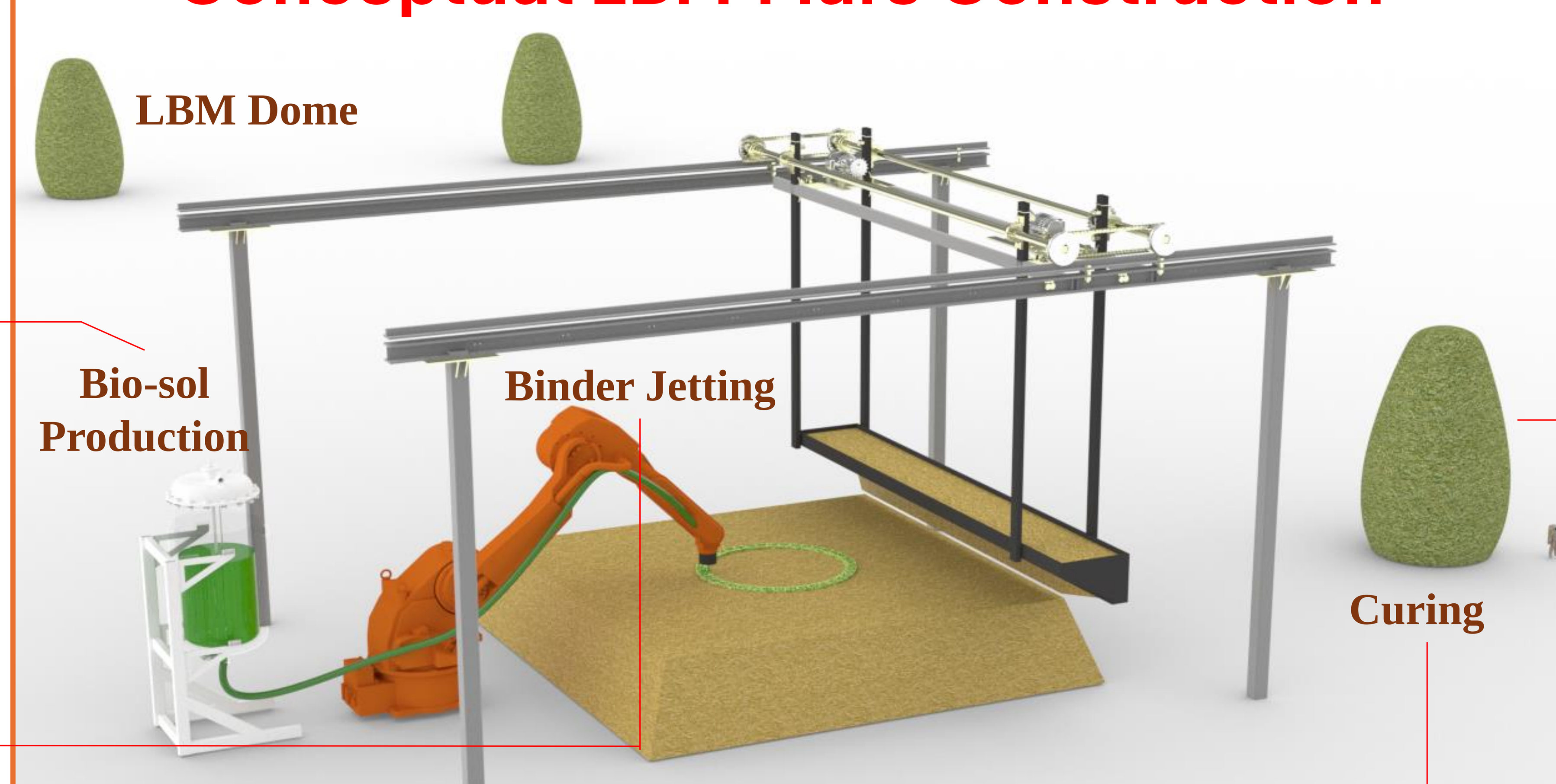
- Combination of intercellular and interfacial adhesions improve LBM strength **twice** than wild one
- Hybrid LBM have **10** times of strength than Wild yeast LBM by:
  - Microstructure improvement: foam → reinforced structure
  - Better chemical compatibility

Hybrid-LBM (yeast + gelatin)



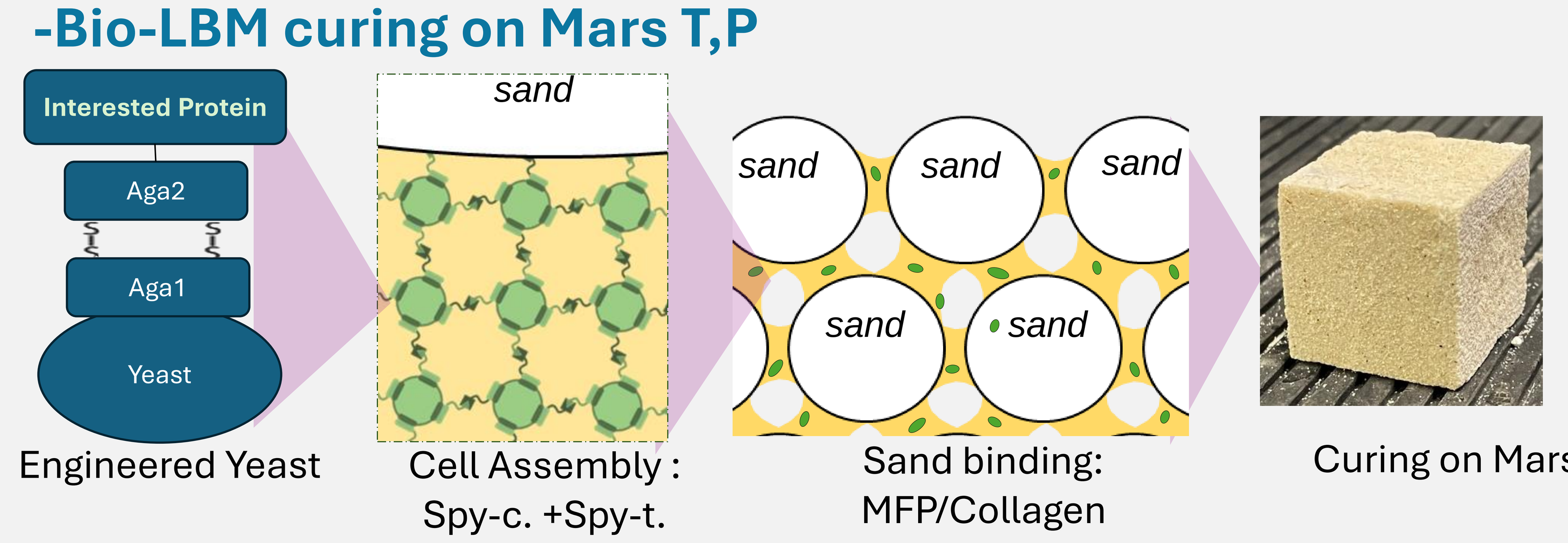


Conceptual LBM Mars Construction



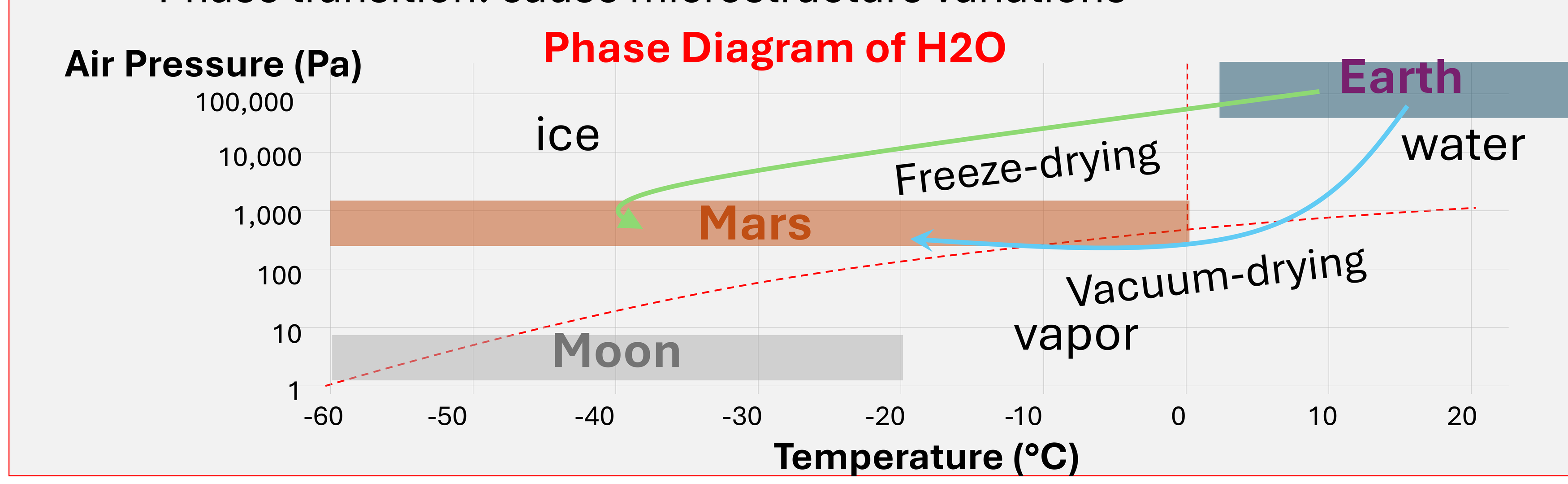
3.Curing

-Bio-LBM curing on Mars T,P



- Possible curing path: freezing-sublimation or vacuum drying
- Phase transition: cause microstructure variations

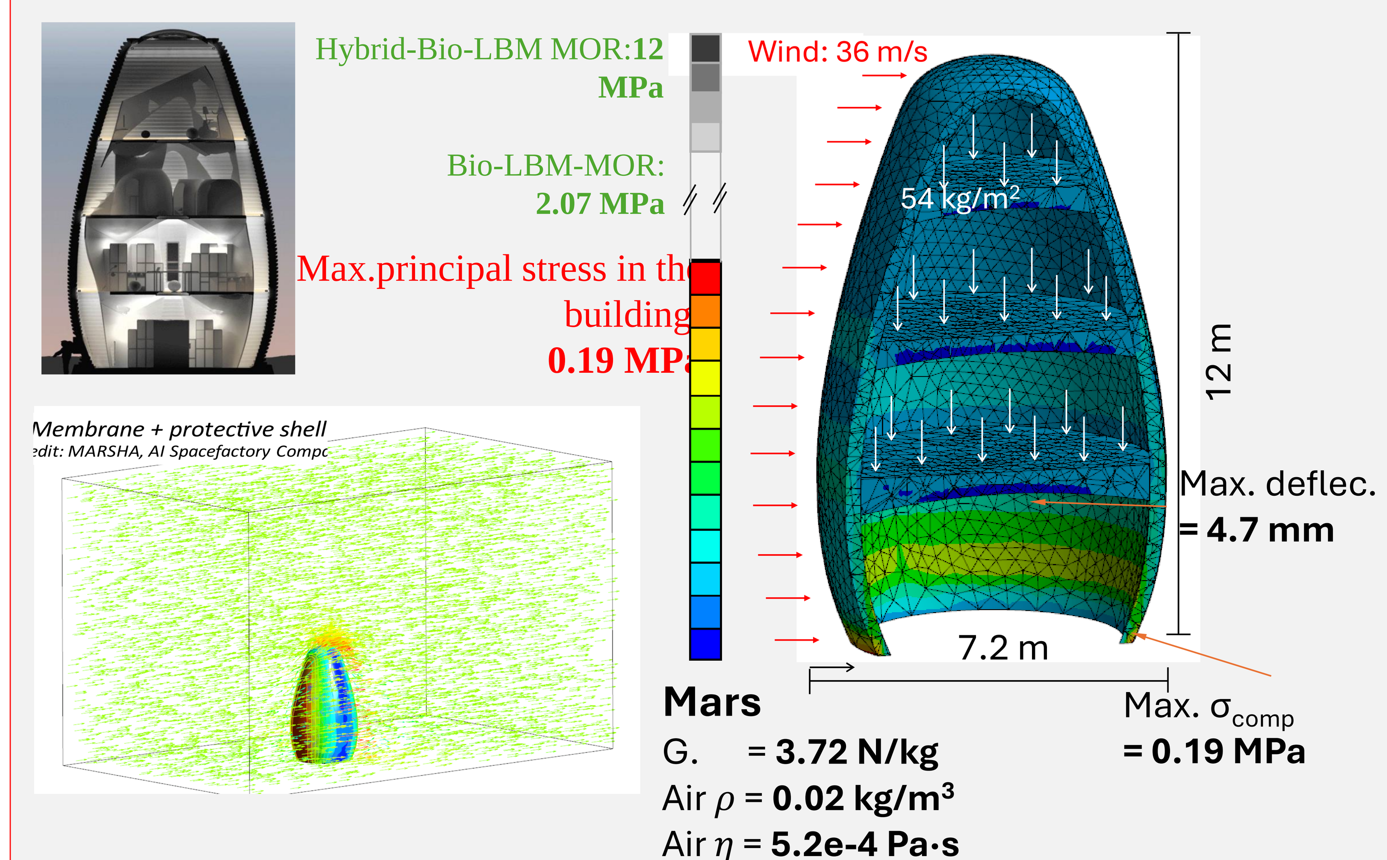
Phase Diagram of H2O



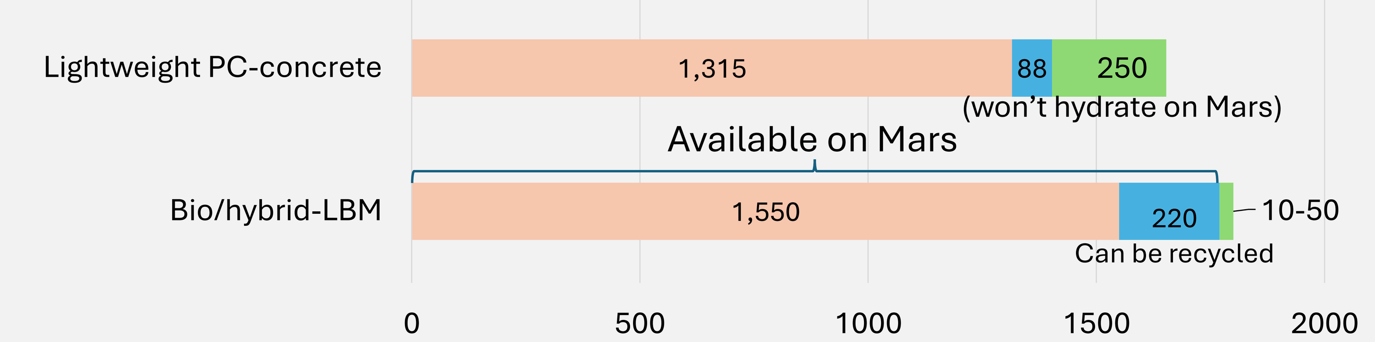
4. Building on Mars

-Structural analysis for Mars loading

LBM Habitat on Mars



Mix proportion (kg/m3)



- Adequate Strength for such an 8 people living dome under
  - Mars gravity
  - Storm
- High In-situ-resource-utilization (ISRU) efficiency

-Extra-terrestrial construction (ETC) materials: state of the art

	Type of generator	Ultralight photovoltaic system
Power generation	Rocket payload for generator M(ton)	50
	Specific power P ($GJ\cdot d^{-1}\cdot ton^{-1}$)	22.5 (on Moon), 3.5 (on Mars)

	Key aspects	Previously studied	Proposed
Power conversion	Heating technology	In-situ heating by laser or microwave	Central heating by electrical resistance
	Energy conversion efficiency η	0.013 (laser) 0.05 (microwave)	0.5
Feedstock melting	Feedstock/melting temperature T(°C)	Regolith, >400 °C	H_2O ice, 0 °C
	Heat for unit feedstock Q ($GJ\cdot ton^{-1}$)	2.45	0.81
	Material binder formed	Ceramics, alloy, cement	Hydrosol
Material formation	Material yield by unit binder V ($m^3\cdot ton^{-1}$)	0.4	4.1
	Material compressive strength	4.5 MPa	4-6 MPa
	Time needed to make 1 m^3 of material Q/(ηPMV)	3.7 h (on Moon) 24 h (on Mars)	<1 h (on Moon and Mars)
	Time needed to make a full-scale shelter	22 d (on Moon) 141 d (on Mars)	2.4 h (on Moon) 16 h (on Mars)

Lunar regolith simulant formed material by concentrated solar light sintering and laser sintering