WORLD LEADER

3DPC MATERIALS TRAINING: LEVEL 1

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DISCLAIMER

INDEX

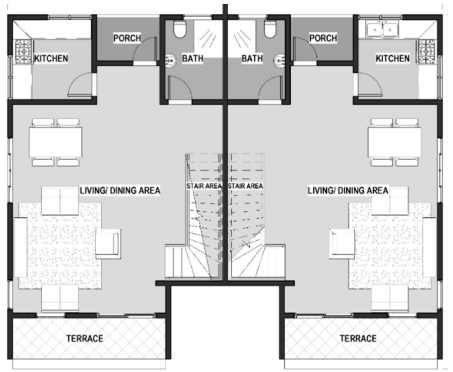
Level 1 (Today)

1. Project recap (5 min)
2. Material process overview: Where are we with the materials (5 min)
3. System overview recap (5 min)
4. Key performance indicators (10 min)
5. COBOD's guide to D.fab (20 min)
6. Break (10 min)
7. Theory of Materials (40 min)
8. Curing (5 min)
9. Safety (5 min)
10. Break (10 min)
11. Test and optional tutorial (30 min)

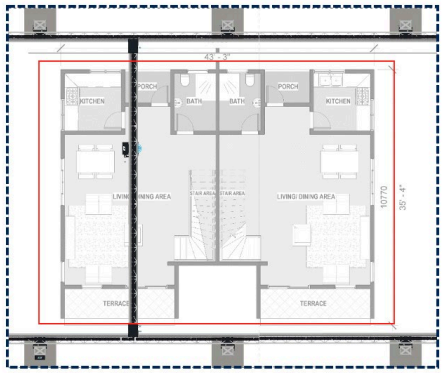
Level 2

1. Standard operating procedures
   - Materials
   - Pump and hose
   - Batchplant
2. Evaluation of material and operator
   - Printability (open time, pumpability, shape retention)
   - Buildabilty
   - Plastic shrinkage cracking
   - Strength

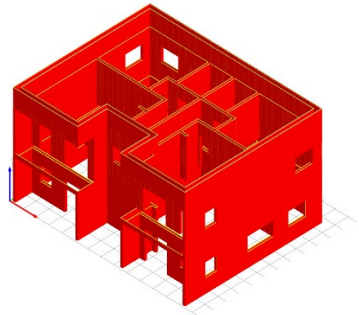
PROJECT OVERVIEW RECAP



Project Design

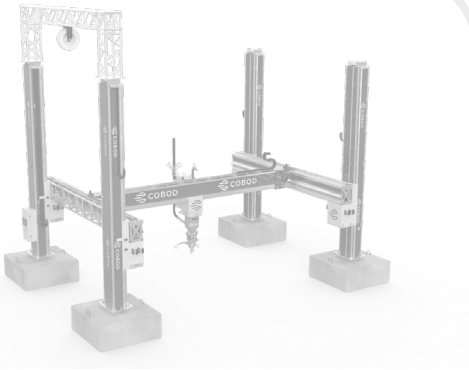


Project Adjustment

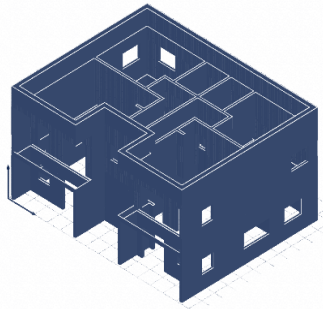


Project Data – **Digital Run**

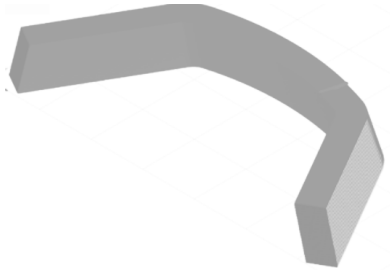
Physical Installation



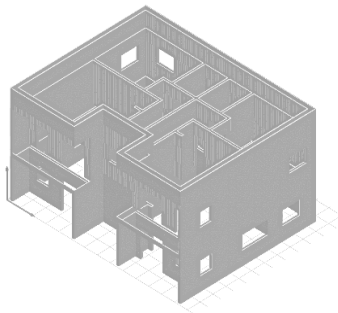
Digital Installation



Project Verification -**Dry Run**



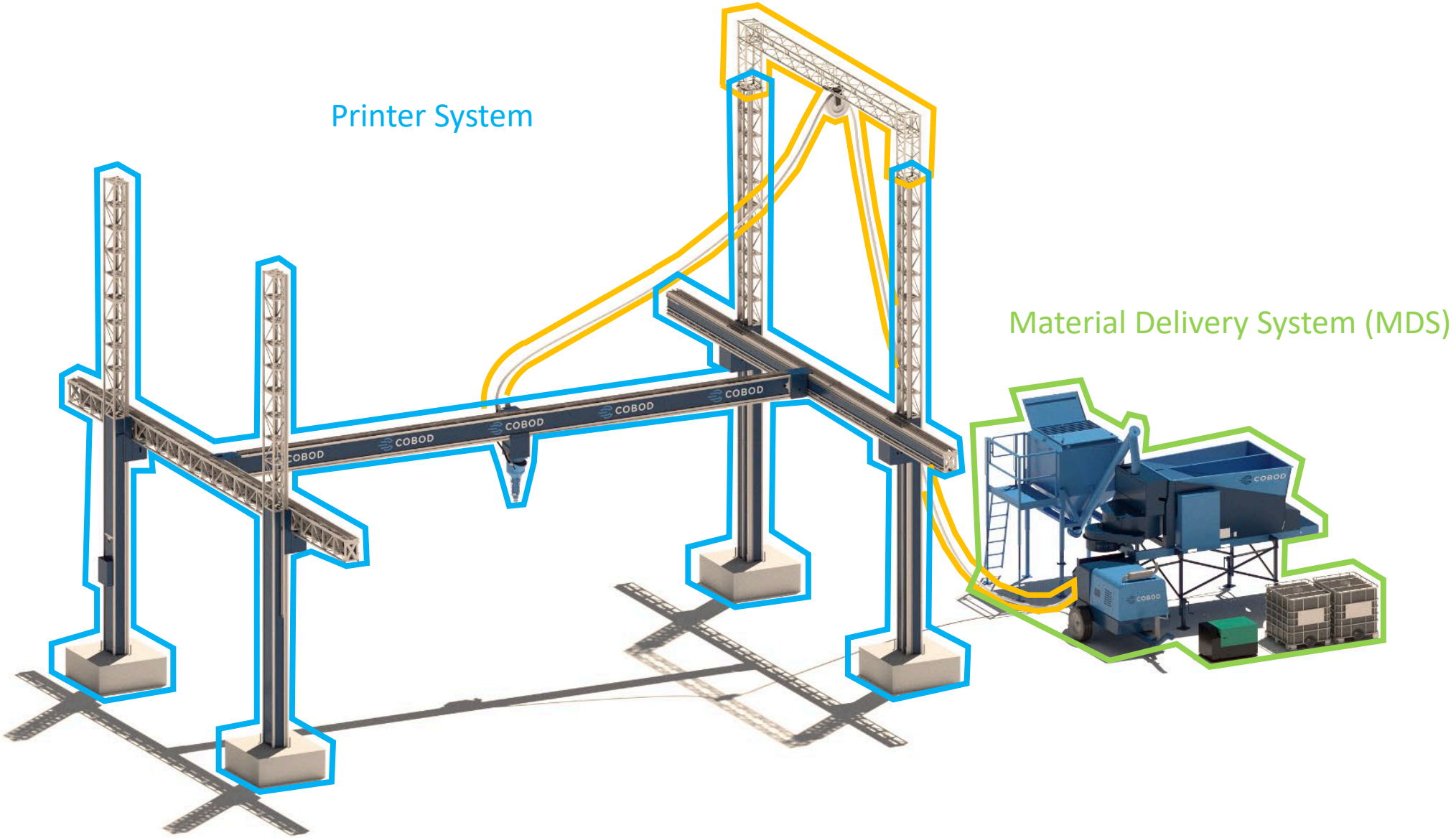
Material Verification -**Wet Run**



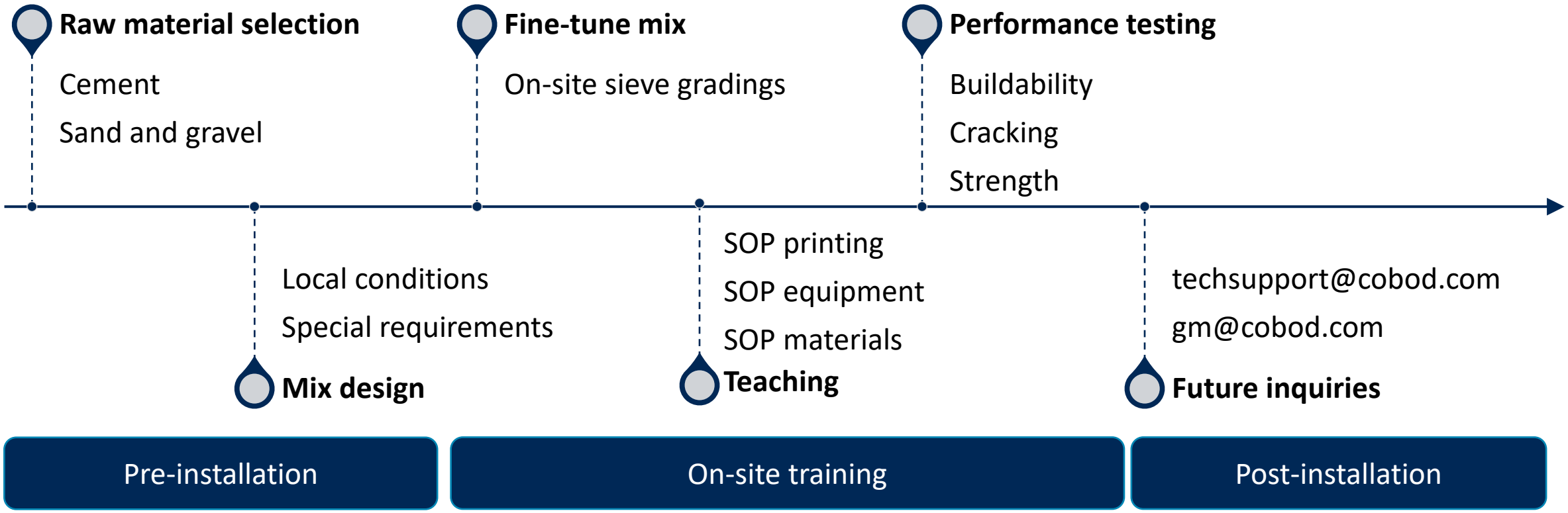
Production

SYSTEM OVERVIEW

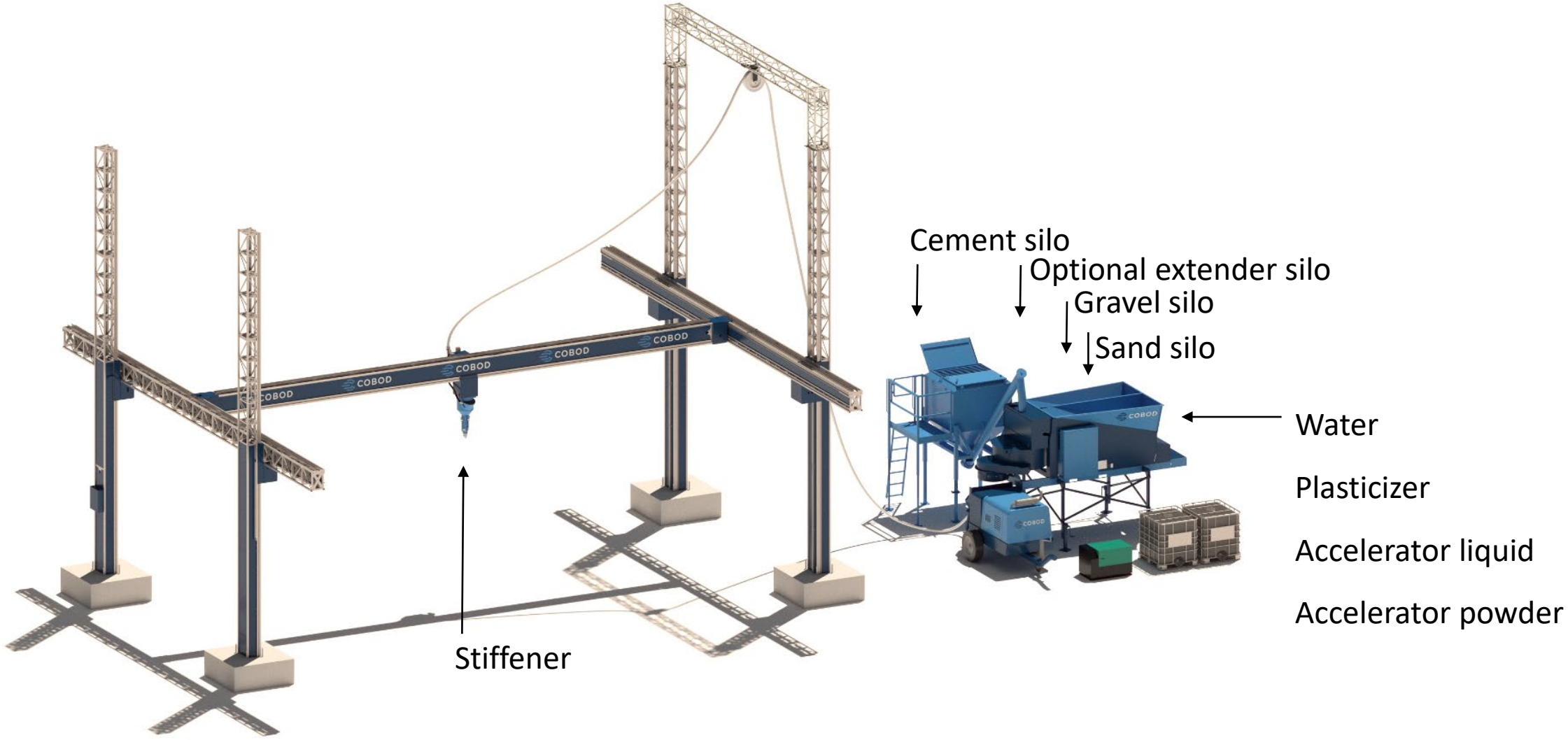
BOD2



MATERIALS PROCESS



SYSTEM OVERVIEW



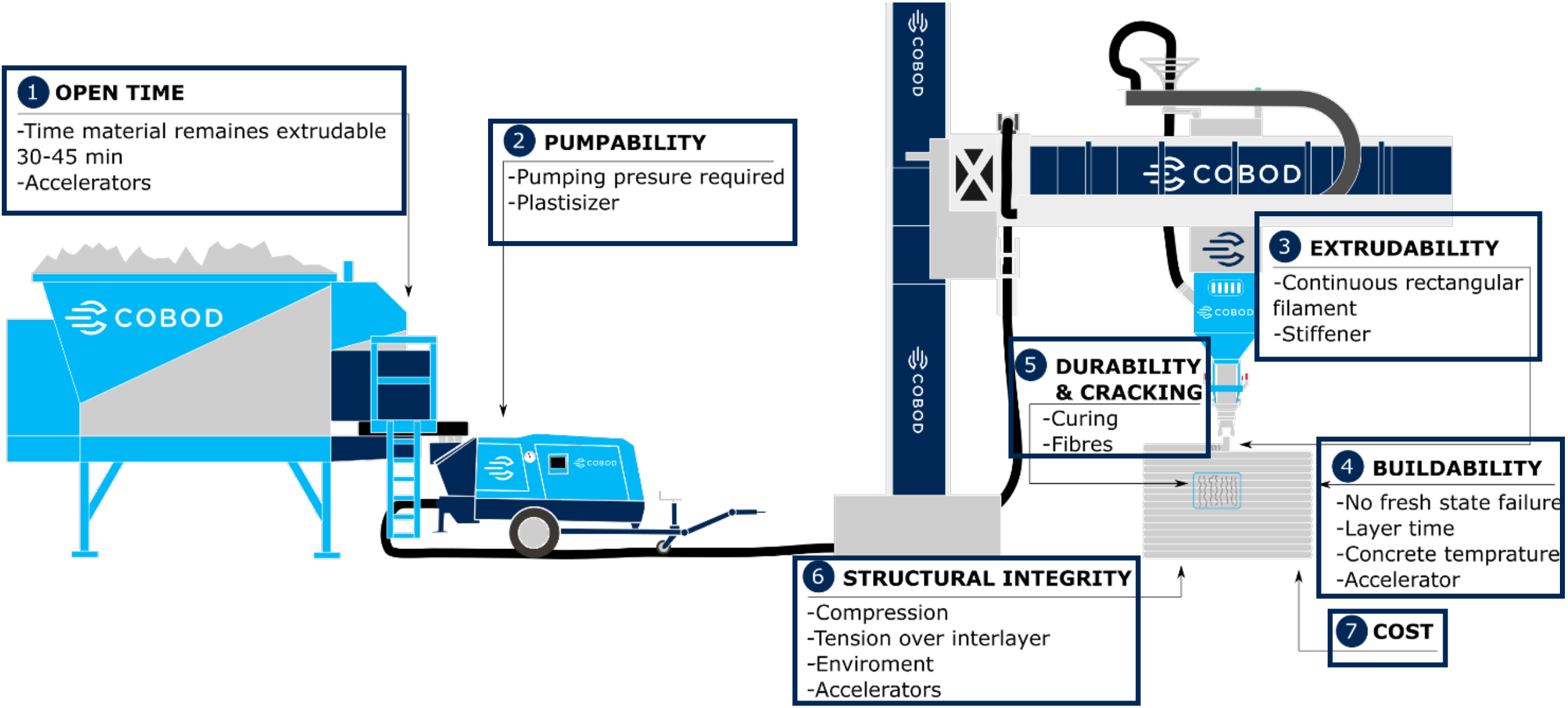
MATERIAL KEY PERFORMANCE INDICATORS

1 OPEN TIME

-Time material remaines extrudable 30-45 min
-Accelerators

2 PUMPABILITY

-Pumping presure required
-Plastisizer



3 EXTRUDABILITY

-Continuous rectangular filament
-Stiffener

5 DURABILITY & CRACKING

-Curing
-Fibres

4 BUILDABILITY

-No fresh state failure
-Layer time
-Concrete temprature
-Accelerator

6 STRUCTURAL INTEGRITY

-Compression
-Tension over interlayer
-Enviroment
-Accelerators

7 COST

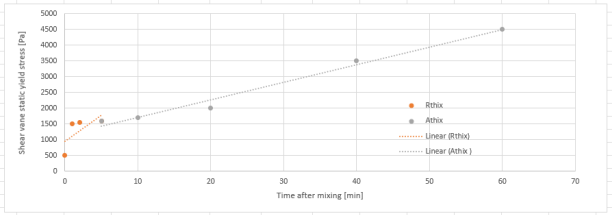
GUIDES

1. Raw material selection
2. Mix design
3. Operation
4. Performance testing

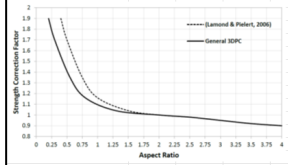
Static yeild stress [Pa]	Mixer	Printhead									
Resting time [min]	0	1	2	5	10	20	40	60	Rthix	Athix	R^2
Mix 1	500	1500	1550	1600	1700	2000	3500	4500	2,74	0,93	0,98
Mix 2	500	1000	1050	1100	1500	1800	2500	3500	1,55	0,69	0,99
Mix 3	700	1300	1450		1600	1700			6,25	0,17	0,86
Mix (select mix here)											
Mix 1	500	1500	1550	1600	1700	2000	3500	4500	2,74	0,93	0,98

Buildability model (Kruger et al. 2020)

Filament shape and print path (Edit here)		
Height [mm]	30	
Width [mm]	50	
Print path length [mm]	19650	
Print speed [mm/s]	80	
Strength corrolation factor	1,15	Read from Figure with Aspect ratio



Information		
Minimum layer time [min] =	4,09375	
Aspect ratio=	0,6	



Answer		
Layer of failure=	25	
Height of failure (mm)=	750	If negative, will not fail at any height
Actual heigh=	200	
Safety factor=	0,267	

CEMEX Building the future™

Client:
Date: May 12, 2022

Instruction: Select the raw materials to use, their dosages and the batch volume

Type	Description	Key parameters	Moisture (%)	Quantities kg/m³	BATCH (metric) 200 [L]		BATCH (imperial) 7,1 [ft3]		Cost/m3 (currecy)	% of total
Cement	Aalborg, CEM I 52.5N	450		450	90,00	[kg]	198,42	[lb]	360,00	34%
Addition	Limestone filler	0		0	0,0				0,00	0%
Water, efficient	Tap water	210		114,4	22,882		50,447			
Admixture 1	D.FAB 3D α. 1.00	2,00%		9,00	1,80		3,97		95,75	9%
Admixture 2	ISOXEL 5450	1,50%		6,75	1,35		2,98		81,86	8%
Admixture 3	ISOXEL 899	1,50%		6,75	1,35	[kg]	2,98	[lb]	101,95	10%
Admixture 4	PP 10-12 mm	0,10%		1,00	0,20		0,44		15,00	1%
Admixture 5	D.FAB 3D β. 1.00			0,50					5,29	0,50%
Fine aggregate	0/4 (sand)	58,8%	6,00%	1034,0	206,80	[kg]	455,91	[lb]	206,80	20%
Coarse aggregate	4/8 (Gravel)	41,2%	2,50%	699,9	139,98		308,60		191,07	18%
			Fresh density =	2322	[kg/m³]			Total=	1057,72	100%

COBOD'S GUIDE TO D.FAB

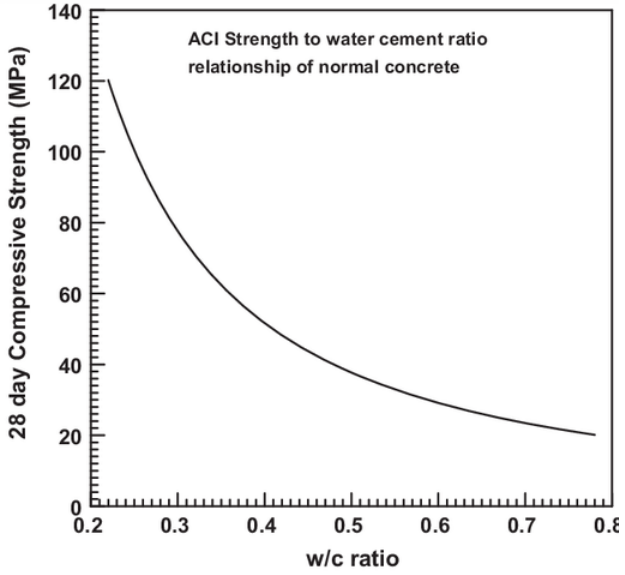
Version 1

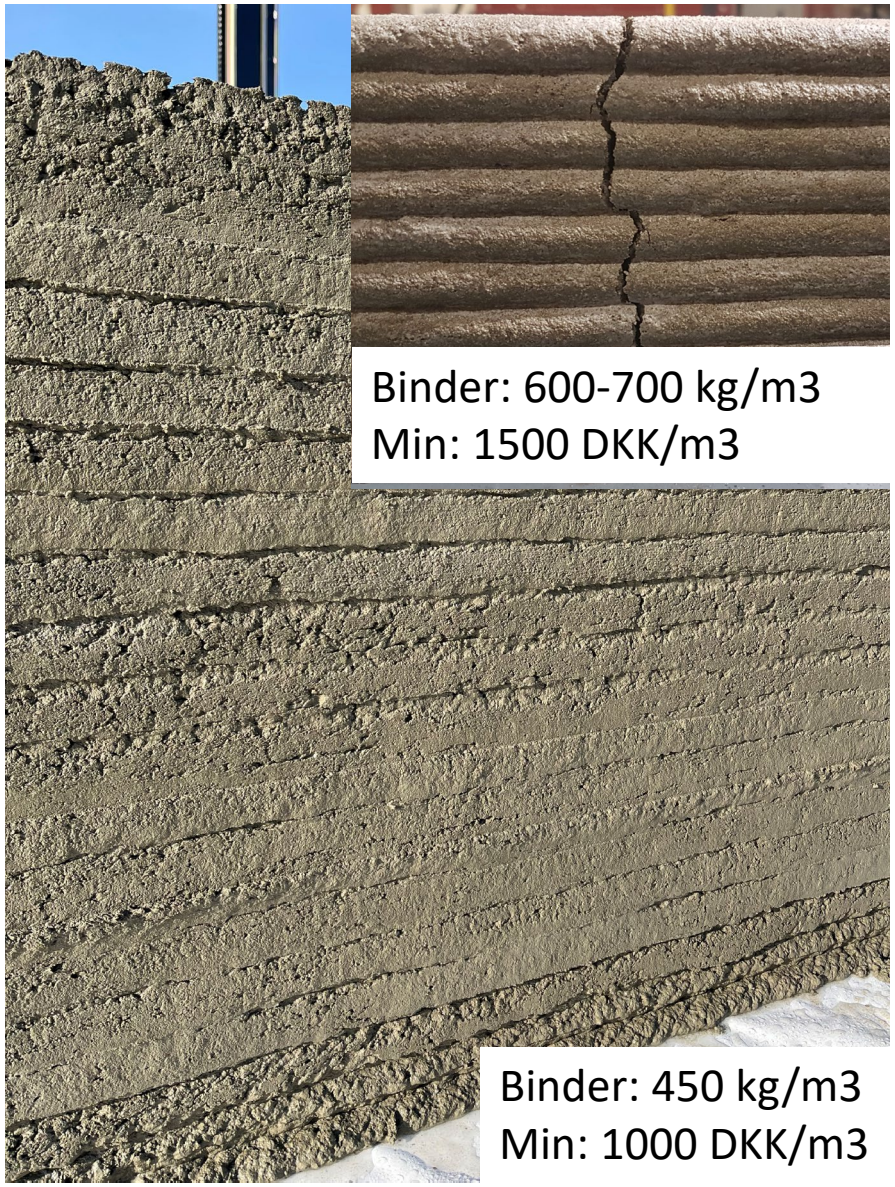
Last update: 26/07/2022

Figure 1: D.fab in Canada

MATERIALS THEORY: BINDERS

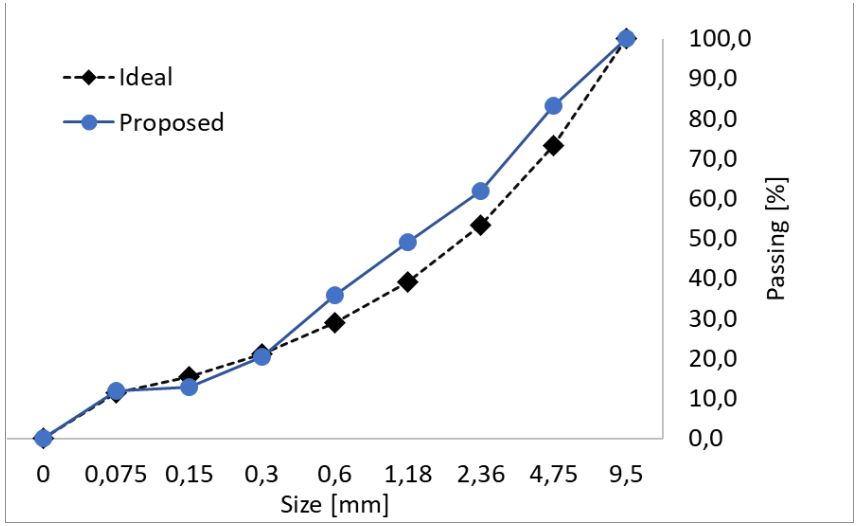
1. Cement
    - Selection based on: strength and extenders
    - 600-700 kg/m3 for mortars, 400-500 kg/m3 for 3DPC, 300 kg/m3 for normal concrete
    - Trade-off: surface finish, pumpability vs cost, cracking
2. Extenders (fly ash, slag, limestone)
    - Selection based on availability, requires additional silo
    - Trade-off: improve surface finish, reduce cost, increase open time vs cracking
    - Recommended: 100-150 kg/m3
3. Water
    - Quantity determines strength
    - Water to cement ratio (W/C)

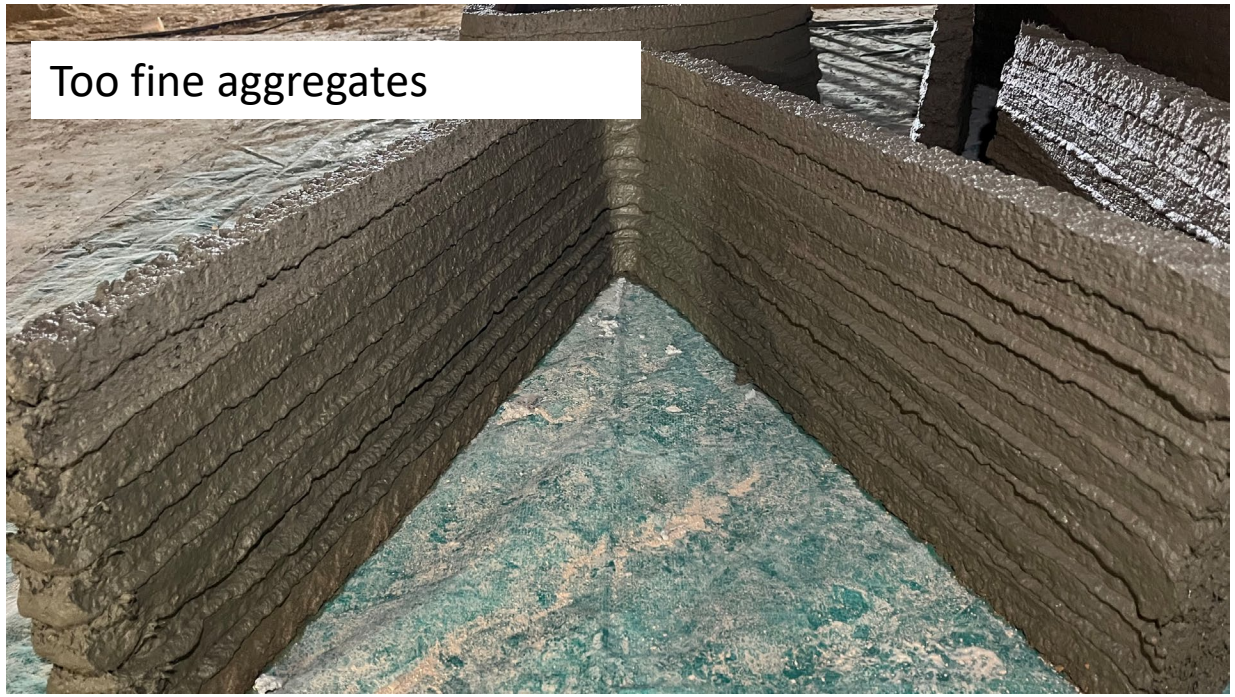




MATERIALS THEORY: AGGREGATES

1. Sand
   - Selection based on particle size
   - Too fine: cracking (mortar), strength reduction (water requirement)
   - Too coarse: bad surface quality, pumpability
2. Gravel
   - Selection based on datasheet information: mainly particle size and source
   - Quantity: particle size

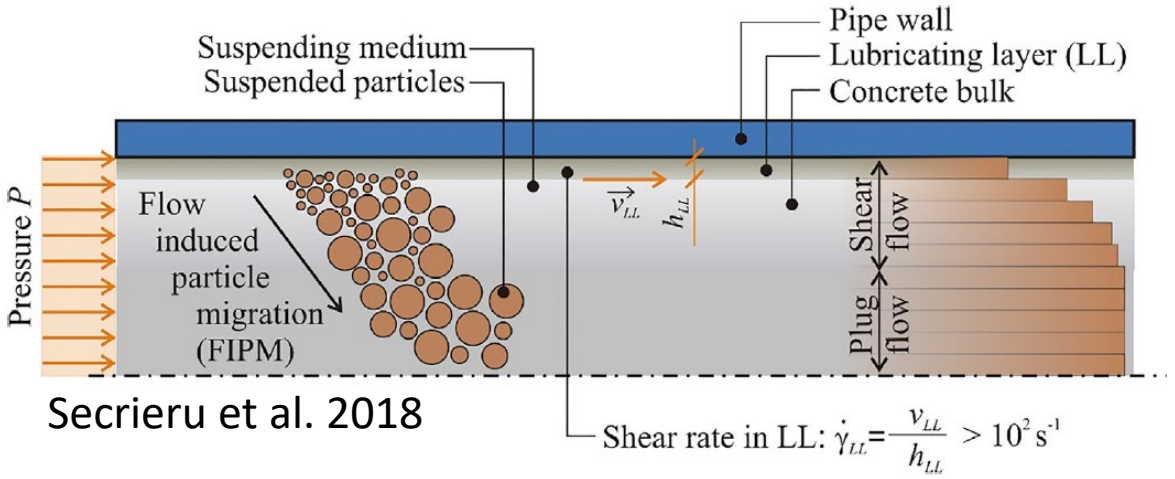




MATERIALS THEORY: ADMIXTURES

Plasticizer

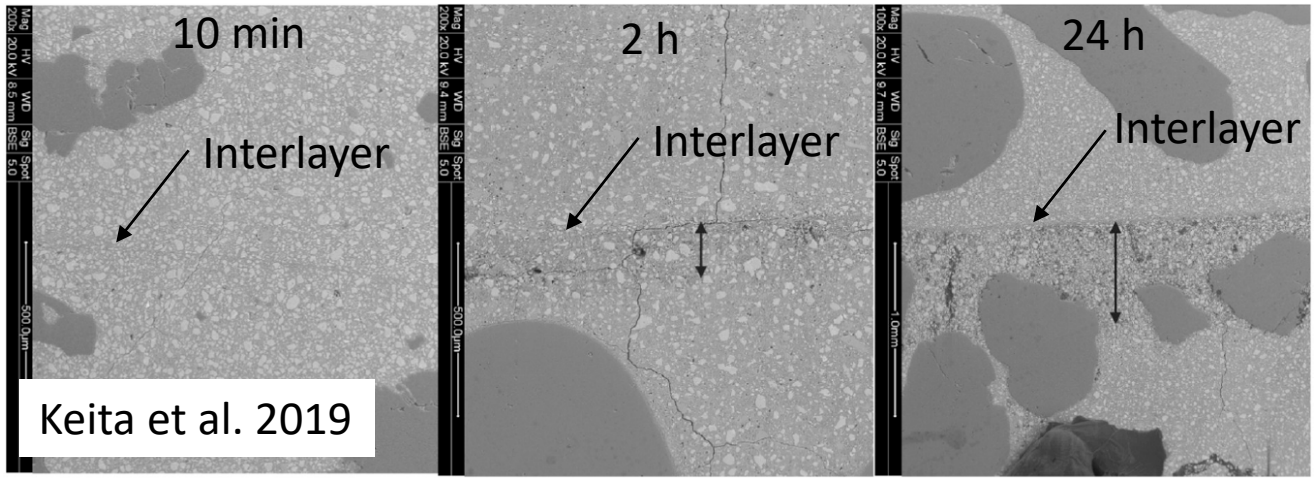
- Reduces the amount of water to make mix fluid, therefore increasing strength
- Too high dosage: retard setting, reduce strength, cost
- Too low: Segregation, low strength
- Recommended: 1,8%



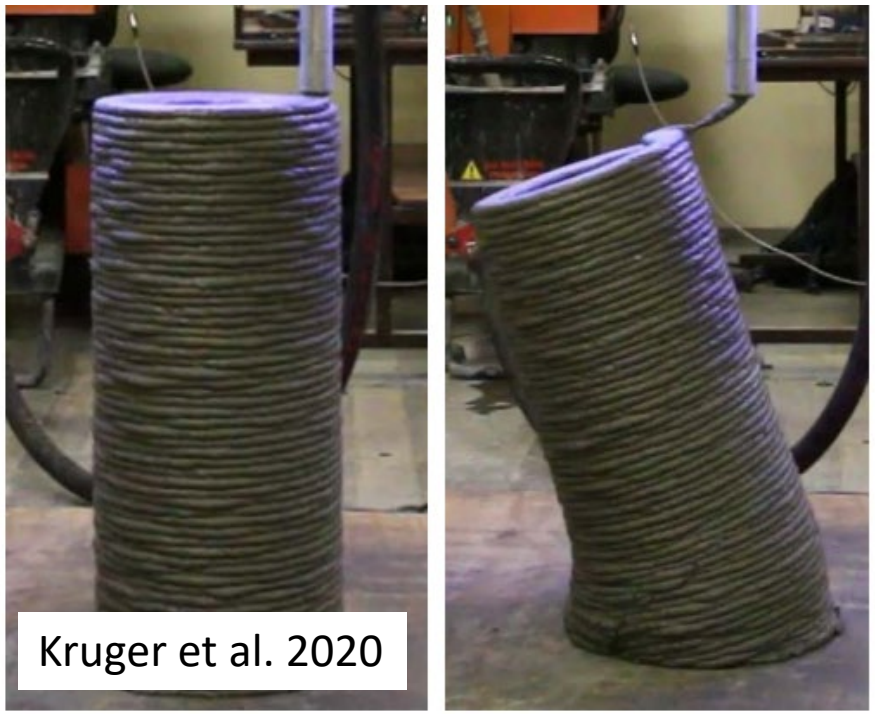
Secrieru et al. 2018

Accelerators

- Reduce open time to increase buildability
- Too low: buildability issue
- Too high: lack of interlayer bonding, open time
- Dependent on: concrete temperature, but also the layer time



Keita et al. 2019



Kruger et al. 2020

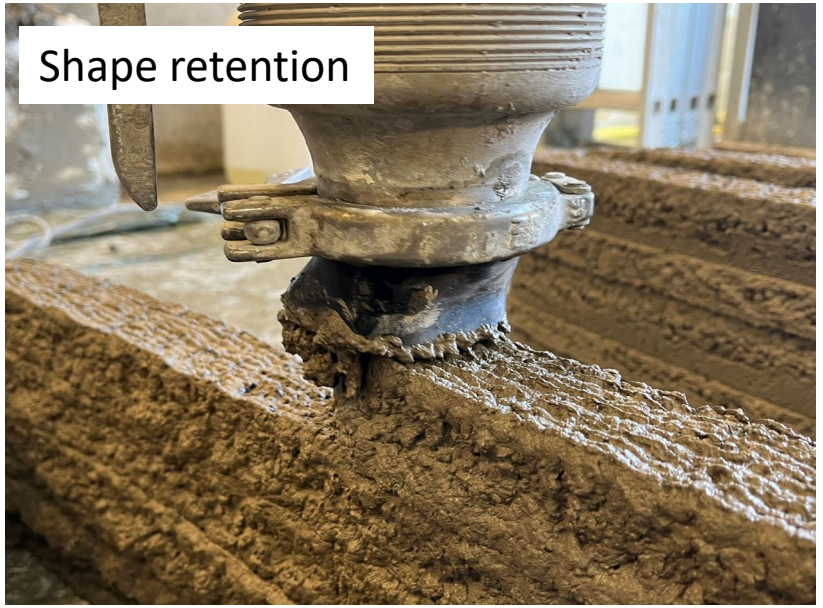
MATERIALS THEORY: ADMIXTURES

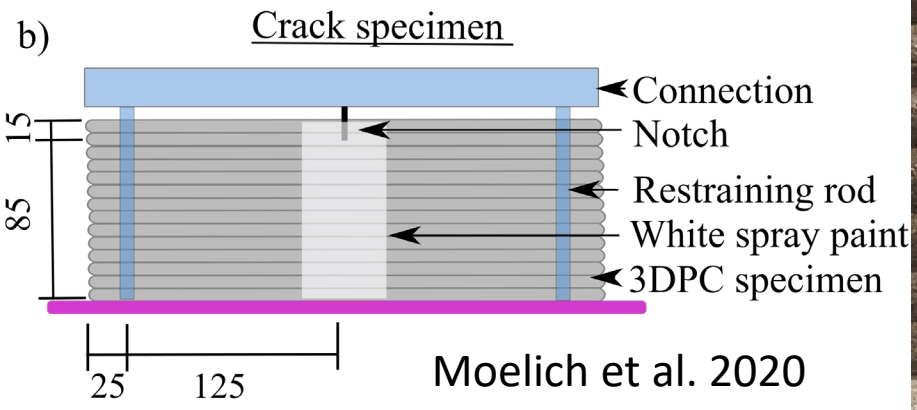
Stiffener

- Shape retention, does not slump at extrusion
- Too high: filament tearing, clogging in the nozzle
- Immediate effect, not to be confused with buildability

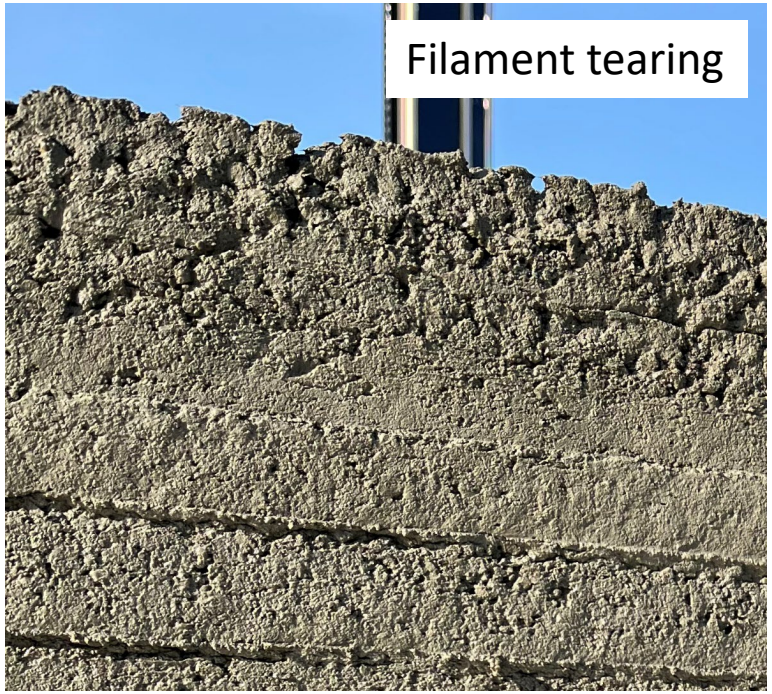
Fibres

- Prevent cracking and filament tearing
- Minimum dosage: 0,1%
- Maximum dosage: clogging





Moelich et al. 2020



CURING IS IMPORTANT!!!

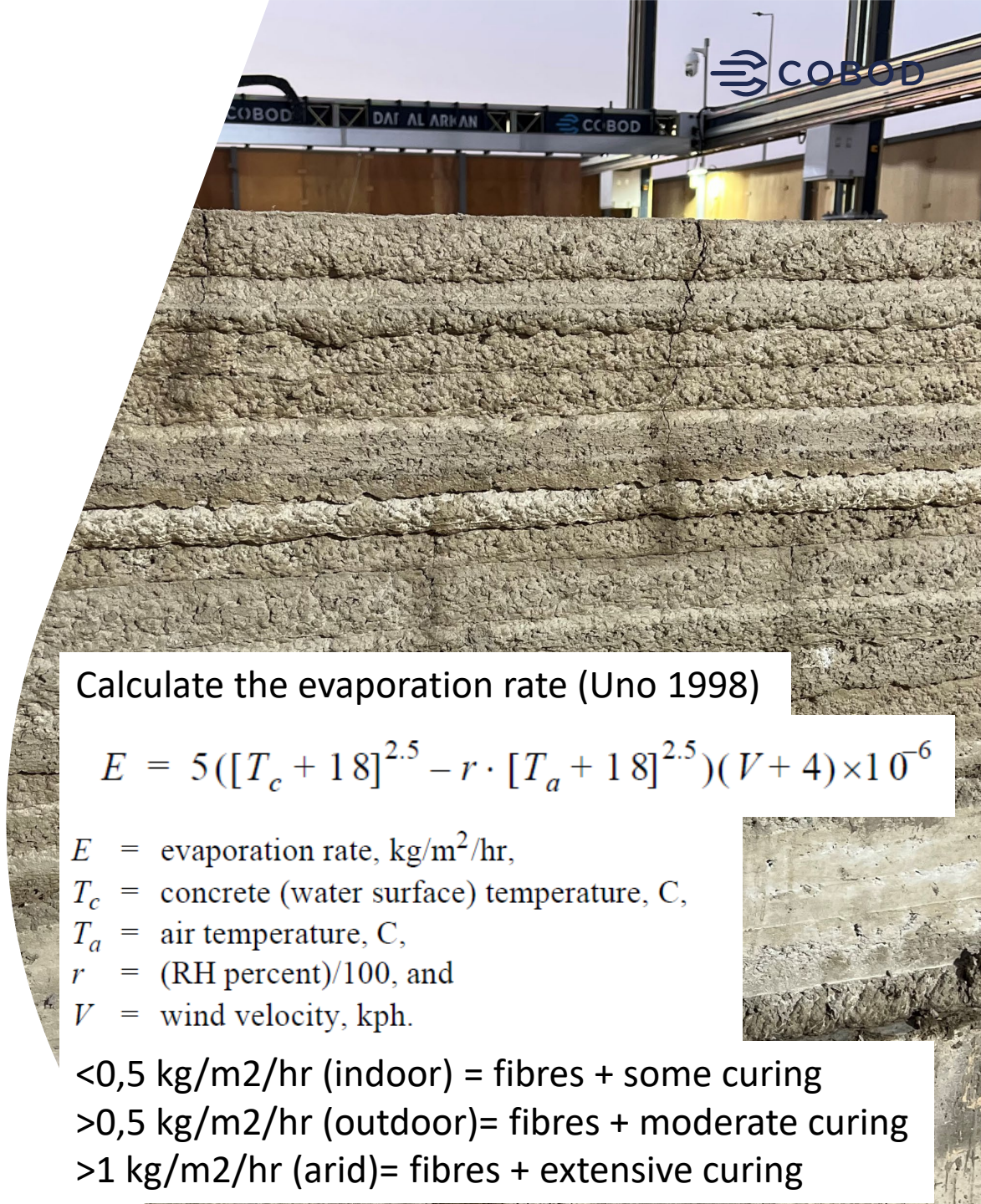
Why do the 3DPC crack soon after placement?

1. Fresh concrete contains water
2. Water is lost to the environment through drying
3. Cause shrinkage and cracking

Curing is about preserving the water inside the fresh concrete

Methods

1. Place concrete at a lower temperature (cool water)
2. Increase the humidity of the printing environment
3. Spray water mist onto the concrete during printing
4. Cover in wet burlap after printing
5. Seal with a waterproof tarp



Calculate the evaporation rate (Uno 1998)

$$E = 5([T_c + 18]^{2.5} - r \cdot [T_a + 18]^{2.5})(V + 4) \times 10^{-6}$$

E = evaporation rate, kg/m^2/hr,
T_c = concrete (water surface) temperature, C,
T_a = air temperature, C,
r = (RH percent)/100, and
V = wind velocity, kph.

<0,5 kg/m2/hr (indoor) = fibres + some curing
>0,5 kg/m2/hr (outdoor)= fibres + moderate curing
>1 kg/m2/hr (arid)= fibres + extensive curing

SAFETY

This is a construction site!

1. Personal protective equipment
2. Proper maintenance and cleaning of equipment

TEST TIME ☺

https://www.flexiquiz.com/SC/N/3DprintingconcretewithCOBOD

TAKE HOME TUTORIAL

ABC construction is located in Cape Town, South Africa. The average temperature is 18ºC.

1. You are provided with three cement types, which is suitable for D.fab and why?
2. Which sand type is best suited for 3D printing concrete?
3. What gravel to sand ratio do you recommend with Sand A and Gravel A?
4. What accelerator dosage do you recommend?
5. What mix design do you recommend?