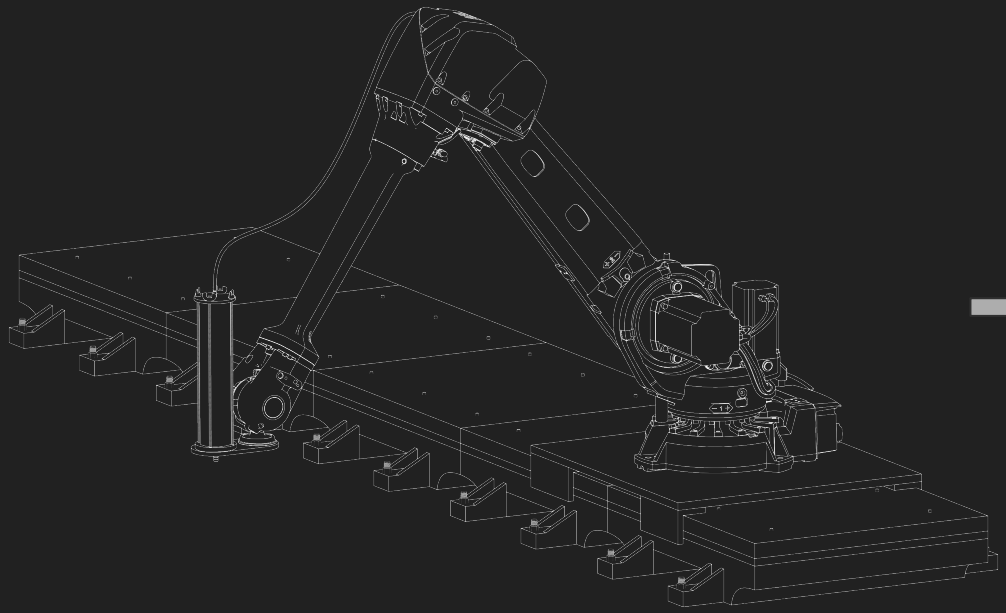
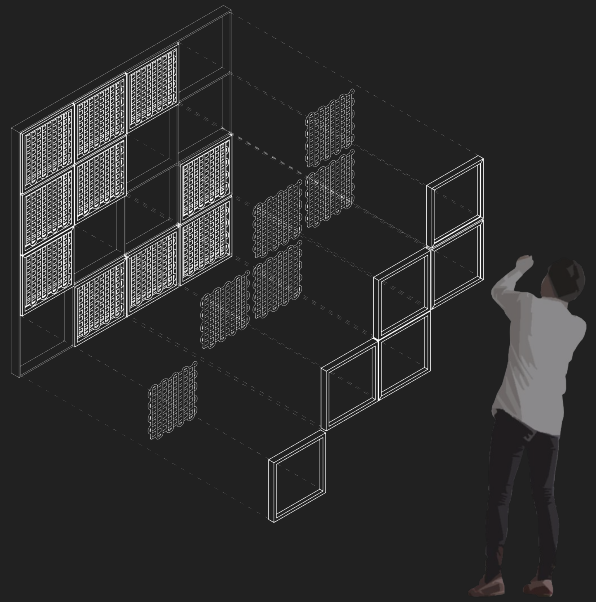
Clay Extruded Facade

By: John Braun, Renzo Eseo, David Skup





Clay Extruded Facades

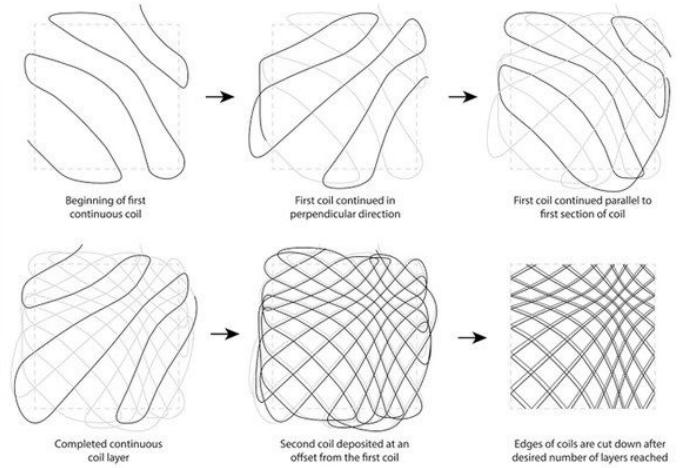
By: Jared Friedman/Olga Mesa/Hea Min Kim

Place: Harvard University

The team appropriated a robotic arm from a factory floor, bolted a giant clay-filled syringe to it, and employed a printing process developed by the Harvard Graduate School of Design Robotics Group.

CAD files that specified paths for the robot to follow were used and as it progressed clay was squeezed like toothpaste from the metallic cylinder onto an irregular surface forming a two-foot square panel.

Half-inch thick clay coils were woven, braided, and built-up in patterns on the panel



WORKS CITED

https://www.wired.com/2014/06/harvard-robot-whiz-invents-a-way-to-weave-build-facades-out-of-clay/

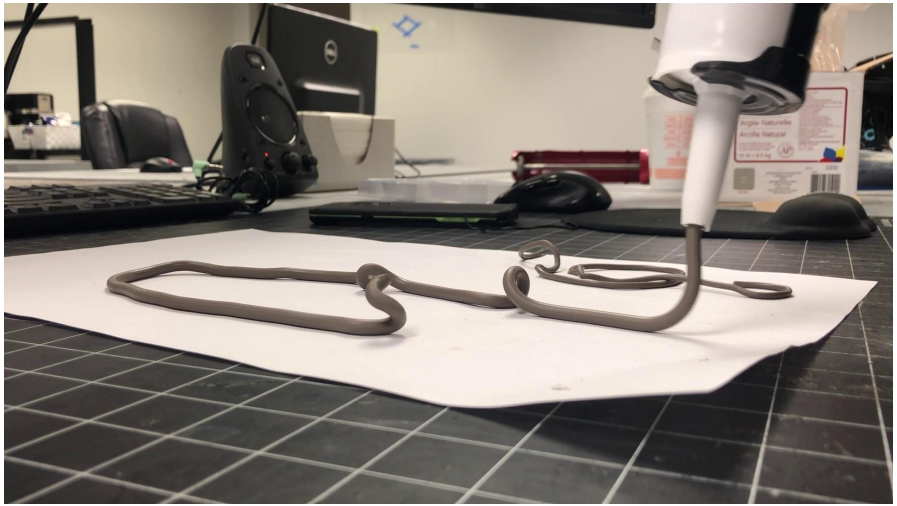
Initial Trials

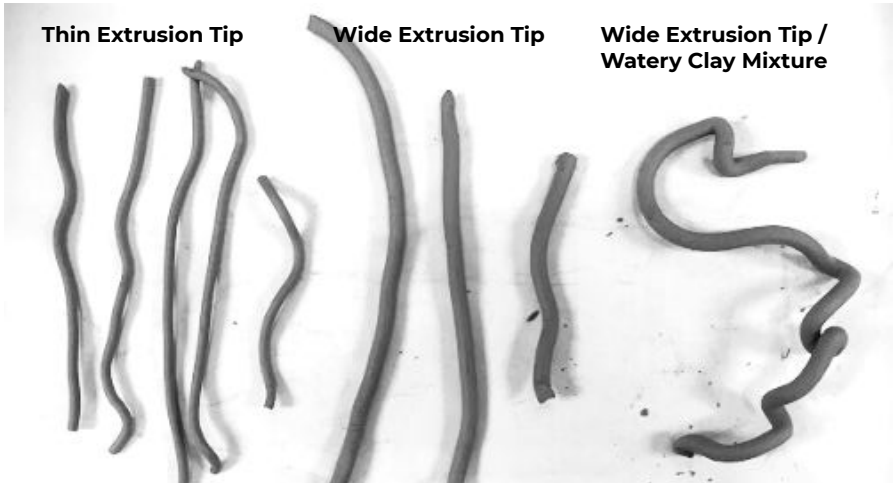
Devices:

Calk Gun, Air Dry Clay

Process:

Loading a Caulk Gun, we experimented with cutting the tips of the extruder to be in different sizes as well as mixing water into the clay to yield the best mixture for extrusion.





Pneumatic Extruder: Assembly

Breakdown of Parts

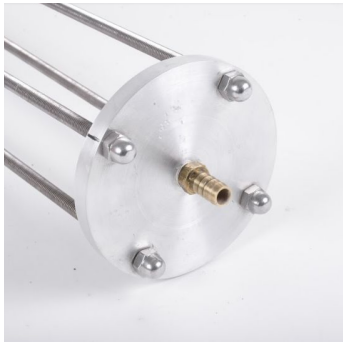
Pneumatic Extruder: Assembly

End Effector Components

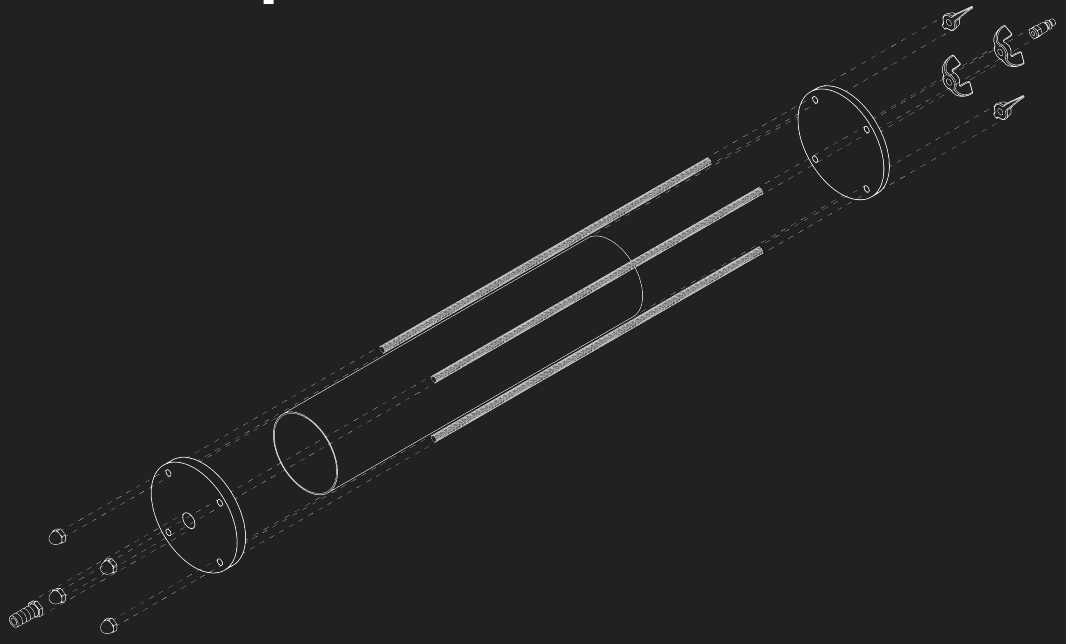






Pneumatic Extruder Development



Process:

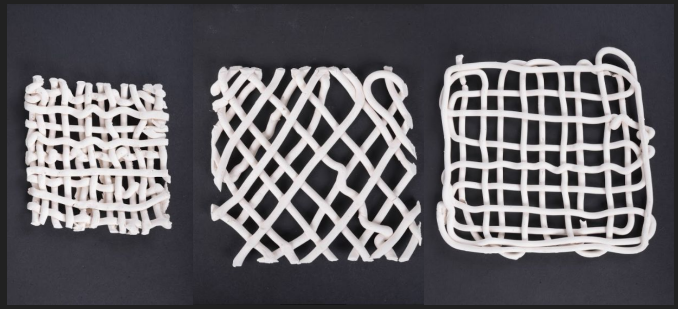
Loading the clay

Pneumatic Extruder

Using the pneumatic extruder, we created patterns by hand

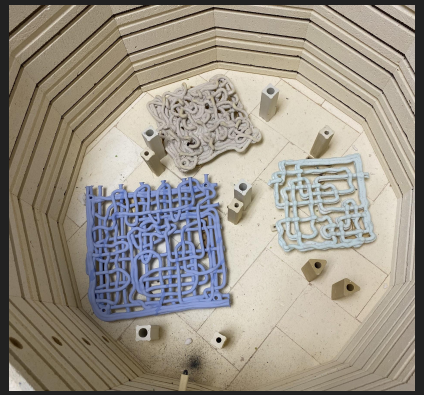
Hand Extruded Panels:

Wet Clay VS Fired Clay

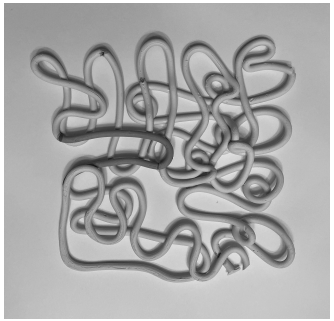


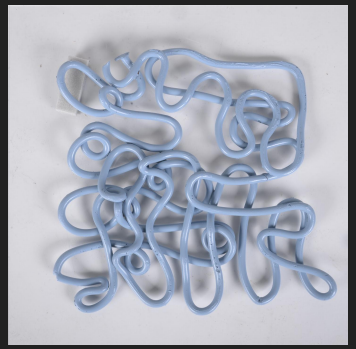
Clay to Kiln

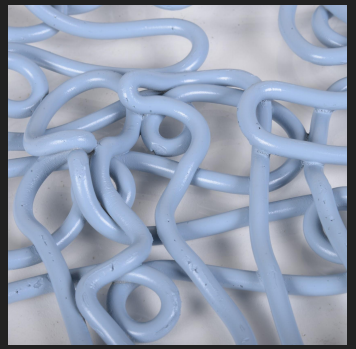
After extruding clay, the pieces were dried for at least a week. They were then packaged and carefully transported to the kiln where they were fired at cone 5 (about 2000 degrees F). The following day, after cooling, they were transported off site, glazed and brought back to bake the glaze coat.

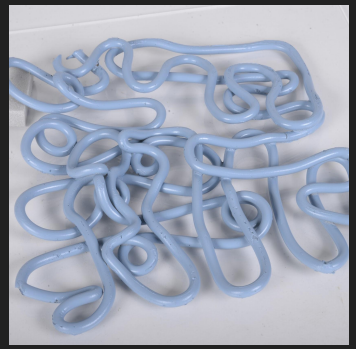


2D Pattern





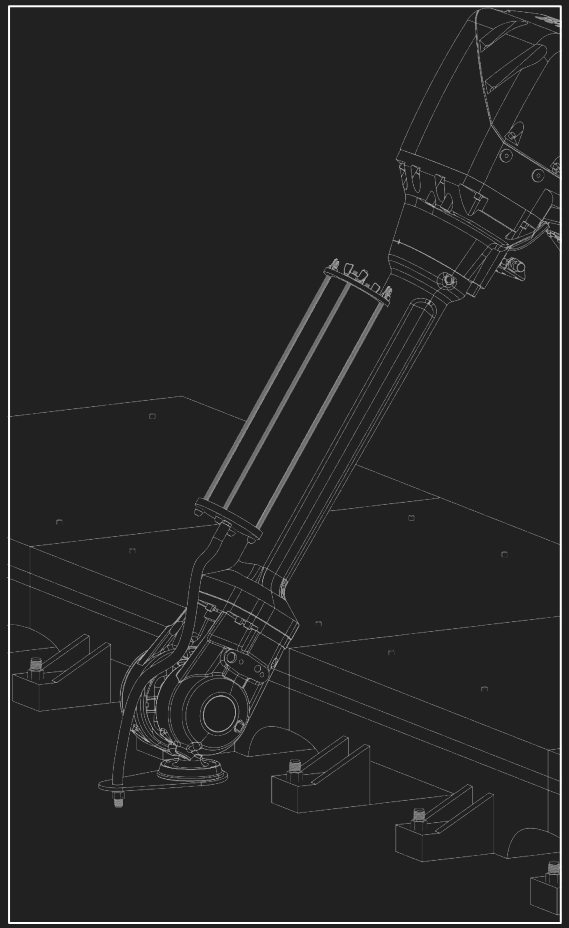




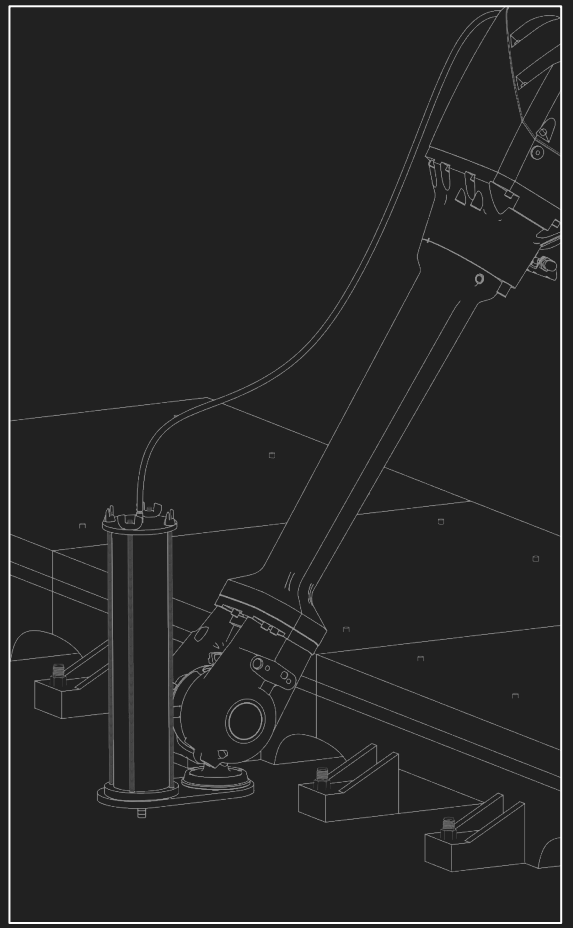
Analysis:

Through a previous failed attempt during hand trials, we learned that the clay extruded much faster without the hose, and so we opted to removing the hose entirely from the system and mounting the extruder on the head of the robot.

Pneumatic Extruder



Hose Attachment



Nozzle Attachment

Comparative Clay Outcomes:

Nozzle Variations

Hose + Nozzle:

The hose was to provide a greater range of motion as the extruder is mounted on the rigid arm of the robot compared to the head; yielded slow extrusion time

¼” Nozzle:

The ¼” nozzle by itself allowed a more consistent flow from the clay, however it proved to be short for certain patterns and designs

4” Nozzle Extension:

The 4” nozzle extension was meant to remedy the deficiency in length of the nozzle; proved to have similar constraints as the hose in terms of extrusion time and pressure

Comparative Clay Outcomes:

Clay Variations:
Mid/High Fire Clay

Buff Stoneware Clay 46 : (Main)

AP (Approved Product) seal in moist form
CL (Caution Label) seal for safety in dry form
Firing range of Cone 5-10 with best results at Cone 5
46-M can be bisque fired to Cone 04 resulting in a porous bisque on which AMACO® high fire glazes are easy to apply.
Shrinkage: Cone 5, 12%; Cone 10, 13.2%
Absorption: Cone 5, 1.8%; Cone 10, 0%

Terra Cotta Stoneware Clay No.77 : (Trial)

Terra Cotta colored bisque that's suitable for all glazes and underglazes.
Mixture of finely ground clays, medium ground clays, and grog makes this an excellent red clay for wide firing range including large scale Raku pieces.
Coarse formula allows air to release easily so large size hand built or wheel thrown pieces will not crack and tile will fire flat without warping.
Shrinkage: Cone 5, 10.5%
Absorption: Cone 5, .9%

Type	Moist Form	Dry Form	Color Range	Suggested Firing Temperature			Suggested Glazes	Shrinkage	Absorption
				Bisque	Glaze	Alternate			
Terra Cotta Stoneware Clay No. 77 Talc-Free	AP	NA	Cone 05 Terra Cotta Cone 5 Rich Red Brown	Cone 04 1971°F 1077°C	Cone 5 2205°F 1207°C	Cone 05-5 1911°-2205°F 1044°-1207°C	Cone 5	Cone 04 6.75% Cone 5 10.5%	Cone 04 9% Cone 5 0.9%
Buff Stoneware Clay No. 46 Talc-Free	AP	CL	Cone 5 Buff Cone 10 Soft Gray	Cone 04 1971°F 1077°C	Cone 5 2205°F 1207°C	Cone 5-10 2205°-2381°F 1207°-1305°C	Cone 5	Cone 5 12% Cone 10 13.2%	Cone 5 1.8% Cone 10 0%

Comparative Clay Outcomes:

- Flow Rate
- Speed
- Rate of Beginning
- Rate of End

Robot Use Checklist:

Tasks To Do in Preparation for Robot's Initial Run:

1. Double Check Pressure of Compressor
2. Make Sure Script is In Check
3. Dry Run Pattern
4. Add oil to the top of the end effector (10 drops)
5. Turn on pressure to test caly flow
6. Make sure height of nozzle is appropriate
7. Table height adjustments with a layer of 1" cardboard (allows for ease of transfer)
8. Lights and camera setup
9. Check for camera view for the unwanted obstructions
10. Pray to God that it works

Tasks To Do When Running Robot

1. Prepare extruding site with plastic
2. Change speed of robotic arm
3. Increase or decrease pressure based on the type of clay
4. Top off oil in end effector (10 drops)
5. Purge pressure lines between each run
6. Run excess clay out of the extruder

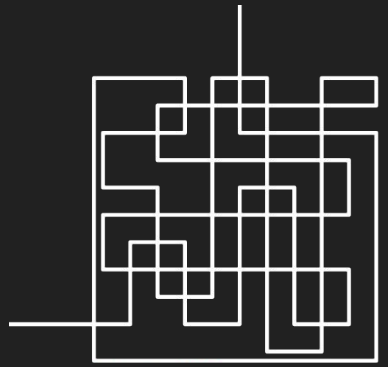
Robot Trials

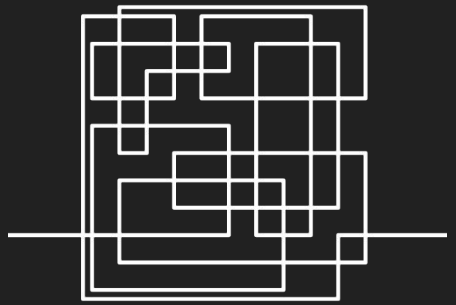
04.11.2019	NAME - TEST #	TEST #	Photo	PATTERN LENGTH (mm)	NOZZLE HEIGHT (mm)	PRESSURE (psi)	SPEED (mm/s)	Note
	PATTERN1	1		3130	170	120	160	.5" CArdboard height is constant thorughout all tests unlesstherwise indicated. John's compressor, directly mounted on extruder
	Rosette 1	1		3708	170	120	200	
	Rosette 1	2		3708	170	120	300	
	BRICK 1	1		6168	170	120	400	
07.11.2019	NAME - TEST #	TEST #	Photo	PATTERN LENGTH (mm)	NOZZLE HEIGHT (mm)	PRESSURE (psi)	SPEED (mm/s)	Note
	Brick 2	1		3520	170	110	40	
	Brick 2	2		3520	170	110	30	
	Brick 3	1		5150	170	110	35	with constant pressure, the clay was coming out slowly
	Brick 4	1		4250	170	110	35	
	PATTERN2	1		3492	170	110	50	The pressure and speed of clay yielded an accurate extrusion
	PATTERN2	2		3492	170	110	50	
	PATTERN2 (on top of pre	3		3492	170	110	50	
	Brick 5	1		3500	170	110	80	the clay seemed to go out faster and so the speed was increased
	Brick 5	2		3500	170	110	80	
	Brick 6	1		7624	170	110	80	due to consistent results, we tried a different pattern to test the theory that the pattern was the problem
	Brick 6	2		7624	170	110	80	
	Brick 6	3		7624	170	110	80	
11.11.2019	NAME - TEST #	TEST #	Photo	PATTERN LENGTH (mm)	NOZZLE HEIGHT (mm)	PRESSURE (psi)	SPEED (mm/s)	Note
	RAINSCREEN1	1		6147	180	110	(from 40) 10	Extension on nozzle, clay came out slower to start, inaccurate pattern
		2		6147	180	110	6	speed was slowed down
		3		6147	180	110	20	Took off extension and replaced with original nozzle; sped up; 3 cardboard thick
		4		6147	180	110	50	increased speed to match the clay
14.11.2019	NAME - TEST #	TEST #	Photo	PATTERN LENGTH (mm)	NOZZLE HEIGHT (mm)	PRESSURE (psi)	SPEED (mm/s)	Note
	RAINSCREEN2	1		8300	270	110	10	4" nozzle & 2 Cardboard + Table for height; Clay was in a bag; yielded a very slow effective speed
	RAINSCREEN2	2		8300	270	150	8	added height of 3/16" acrylic sheet;
	RAINSCREEN2	3		8300	270	130	8	Increased speed and pressure
	RAINSCREEN2	4		8300	270	130	8	Took out bag

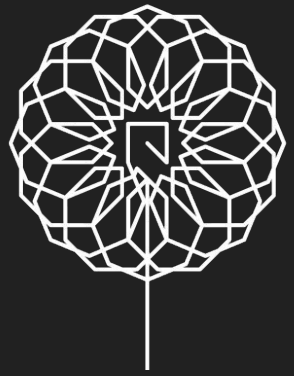
Robot Trials (continued)

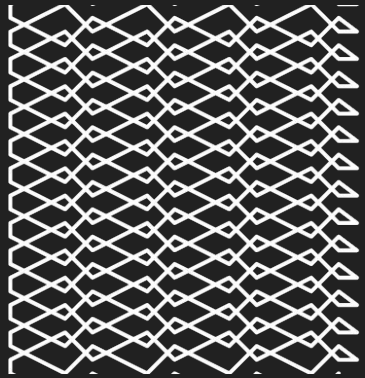
	RAINSCREEN3	1		8305	270	150	15	5 layers of cardboard & 1/4" plywood height; replaced with old nozzle
	RAINSCREEN3	1		8305	270	150	15	
18.11.2019	**NAME - TEST #**	**TEST #**	**Photo**	**PATTERN LENGTH (mm)**	**NOZZLE HEIGHT (mm)**	**PRESSURE (psi)**	**SPEED (mm/s)**	**Note**
	RAINSCREEN4	1		6552	175	130	20	2 cardboard height
	RAINSCREEN4	2		6552	175	130	20	
	RAINSCREEN4	3		6552	175	130	16	the clay was going slower
	RAINSCREEN4	4		6552	175	130	20	the clay reached a more liquidy consistency, and came out faster
21.11.2019	**NAME - TEST #**	**TEST #**	**Photo**	**PATTERN LENGTH (mm)**	**NOZZLE HEIGHT (mm)**	**PRESSURE (psi)**	**SPEED (mm/s)**	**Note**
	Grid Underlay- Big Par	1		18173	160	110	50	
	Transition (grid/pattern) -Big	1		43958	166	110	50	pressure too high, slowed down by a bit and adjusted as the pattern fluctuated
	pattern -Big Panel 1	1		25785	112	125	50	The clay is a harder consistancy
	Grid Underlay	1		18173	160	100	40	
	Pattern	1		25785	166	100	20	
21.25.2019	**NAME - TEST #**	**TEST #**	**Photo**	**PATTERN LENGTH (mm)**	**NOZZLE HEIGHT (mm)**	**PRESSURE (psi)**	**SPEED (mm/s)**	**Note**
	Grid	1		8557	160	110	30	the clay started off slowly and came out faster towards the middle.
	Grid	2		8557	160	110	50	the speed was increased to match the speed of the clay, it came out
	Grid	3		8557	160	110	40	the speed and pressure became more consistant
	Grid	4		8557	160	110	40	
	Grid (double layer)	5		17113	160-170	110		double layer
21.25.2019	**NAME - TEST #**	**TEST #**	**Photo**	**PATTERN LENGTH (mm)**	**NOZZLE HEIGHT (mm)**	**PRESSURE (psi)**	**SPEED (mm/s)**	**Note**
	Grid - Big Panel 2	1		34226	160	110-125	25	the clay extruded slowly at first, we increased the pressure to 125 and yield curly cue
	Grid - Big Panel 2	2		34226	160	125	35	
	Rosette1	1		5500	173	125	35	slower speed yielded a noodle-y testure to clay
	Rosette2	1		5500	173	125	50	faster speed yielded a closer resemblace to 2D Pattern
	Rosette3	1		5500	173	125	35	
	Rosette4	1		5500	173	125	50	clay ran out, loaded different clay
	Grid	1			160	125	20	running the grid pattern, we slowed down the speed to half the effective speed to creat a curly pattern thorugh straight lines

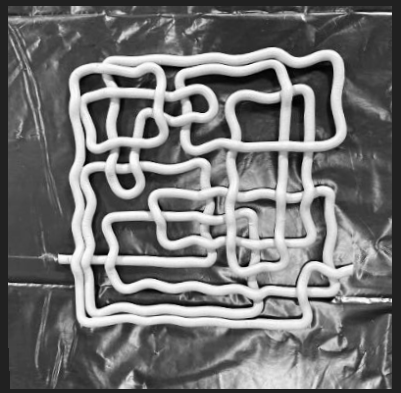
2D Patterns:



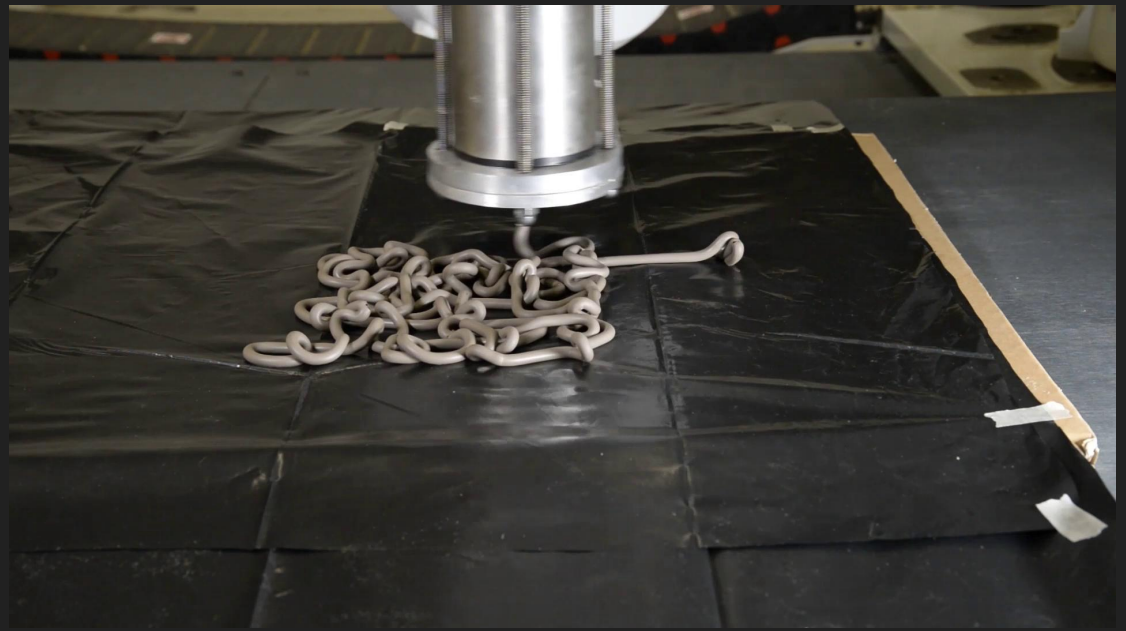


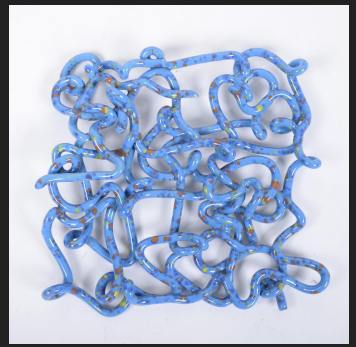


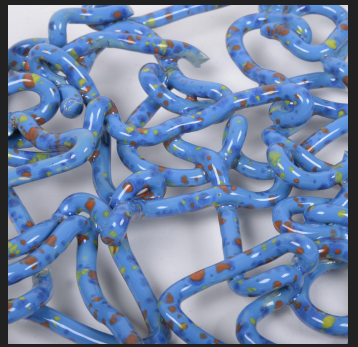




2D Pattern

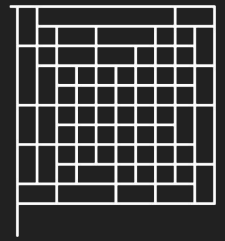


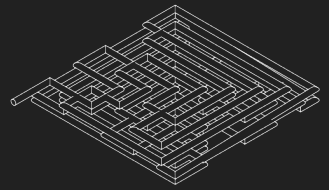


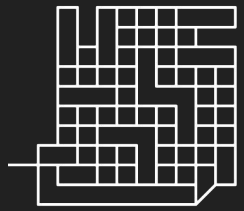


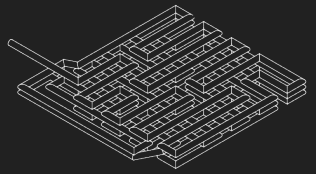
2D Patterns

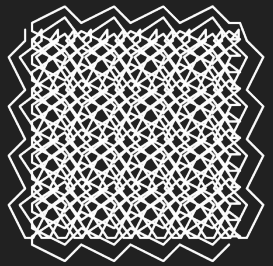
Multiple Layered Patterns:

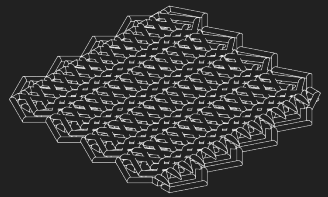


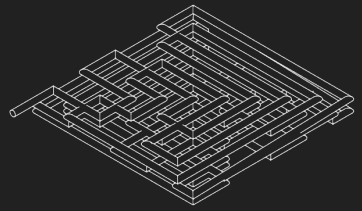


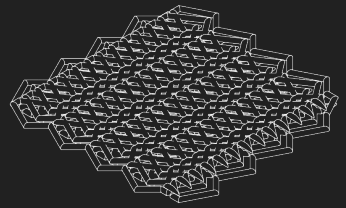


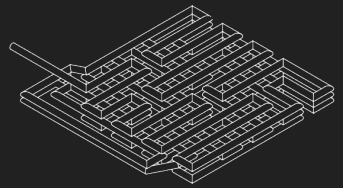












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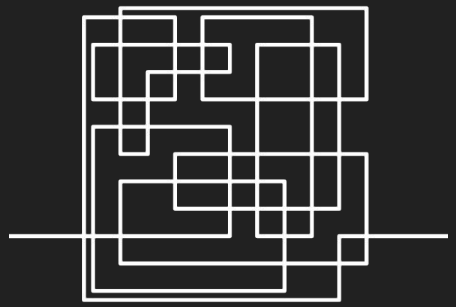
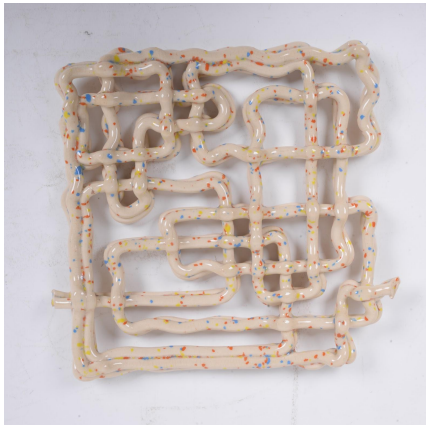
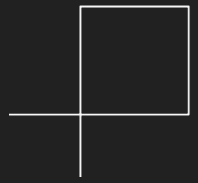
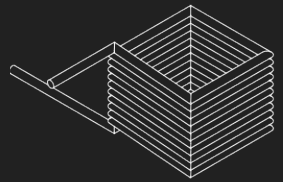
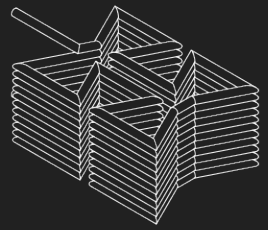


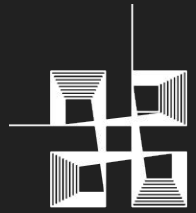


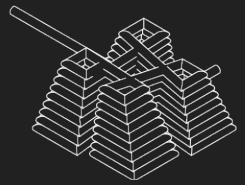
Brick Patterns:

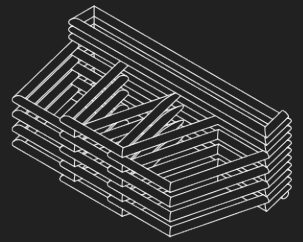












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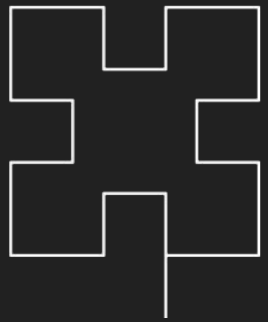
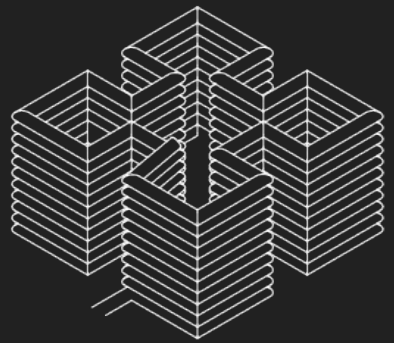
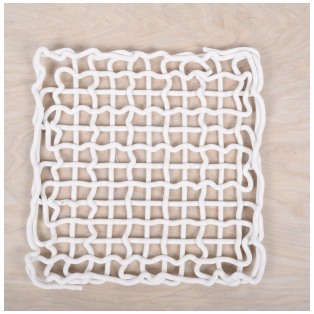


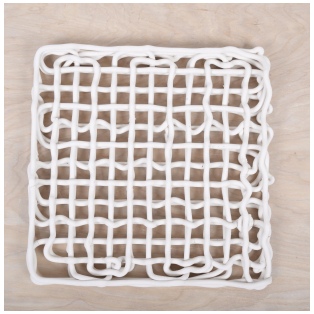
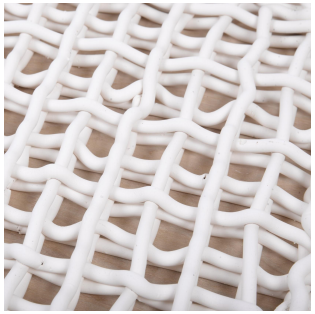


Grid

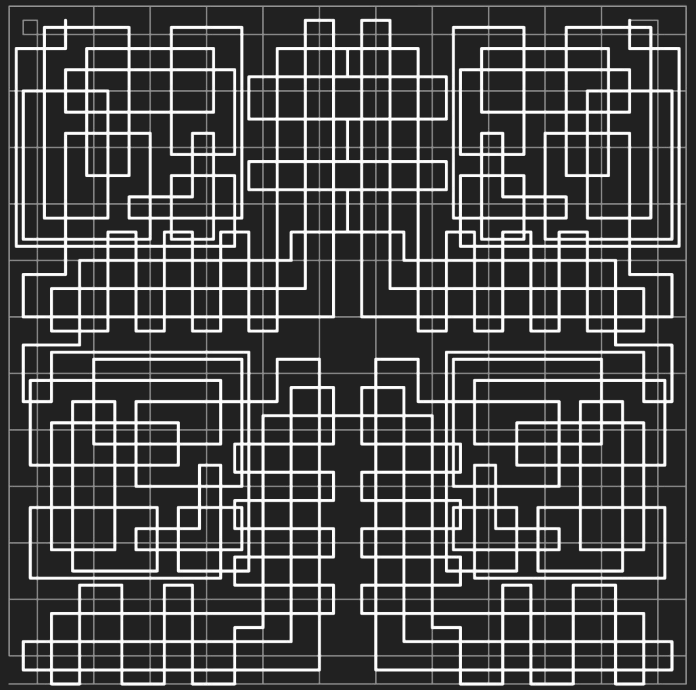
1 layer VS 2 layers

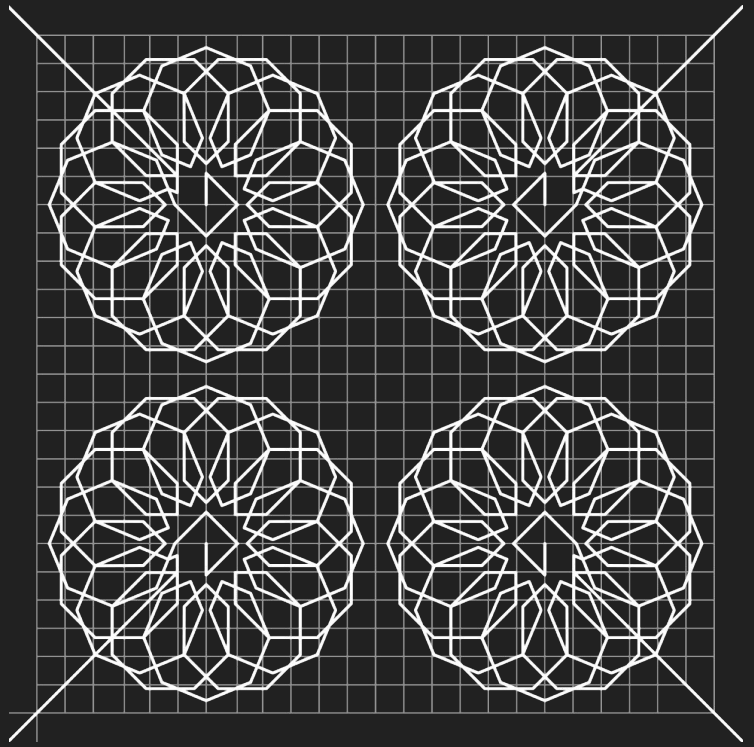




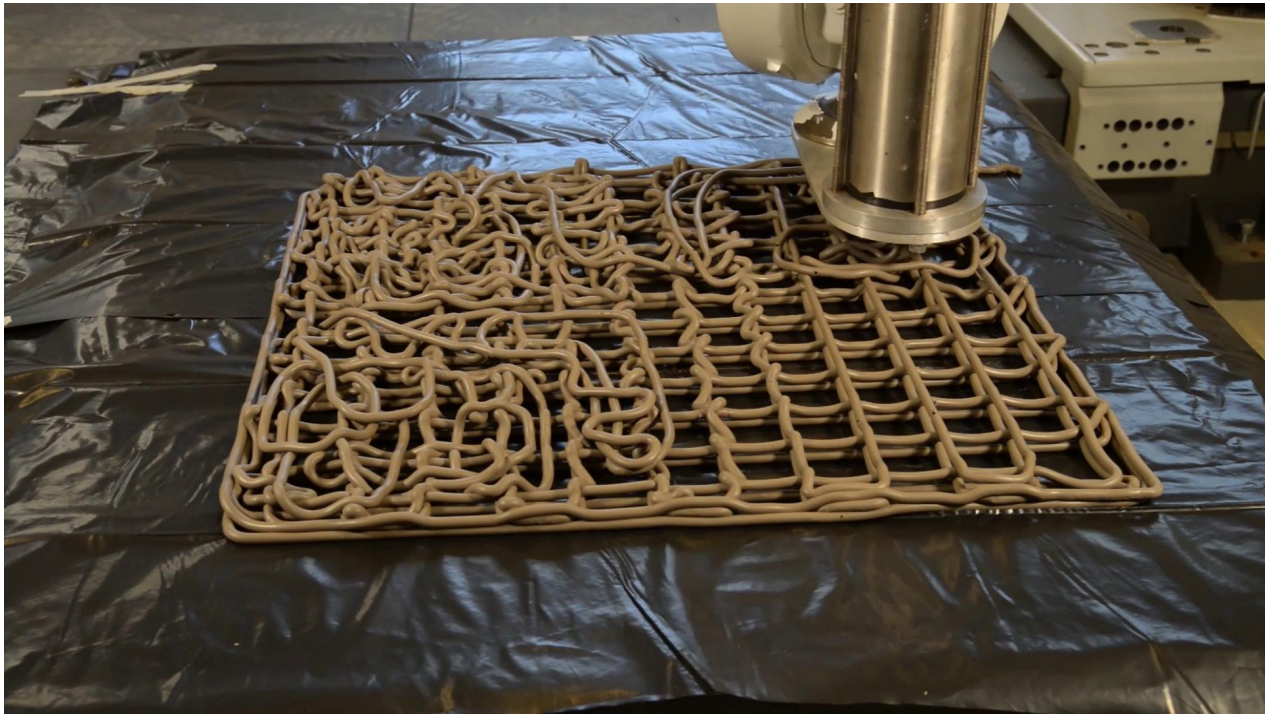
Rainscreen:



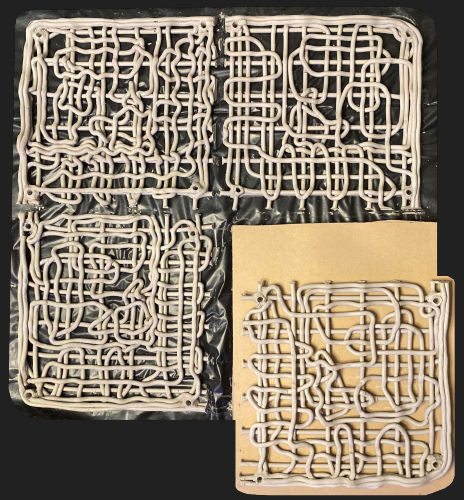


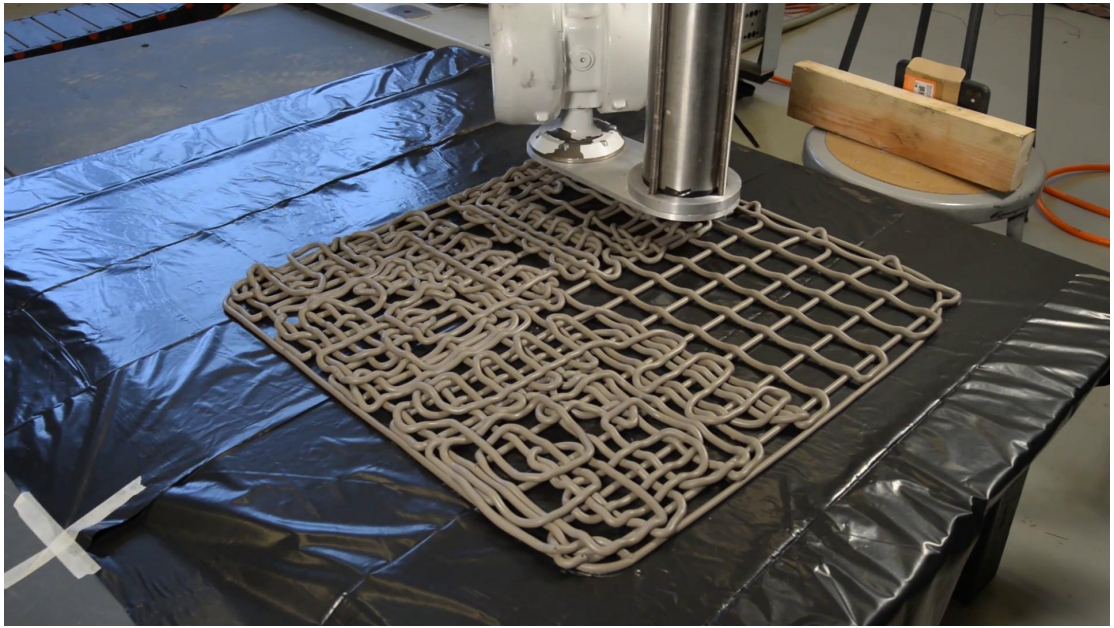
Rainscreen - 1

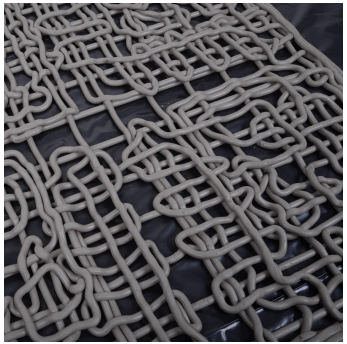
2 Layers



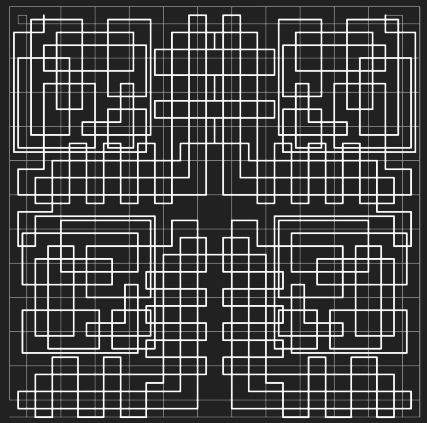
Rainscreen - 1

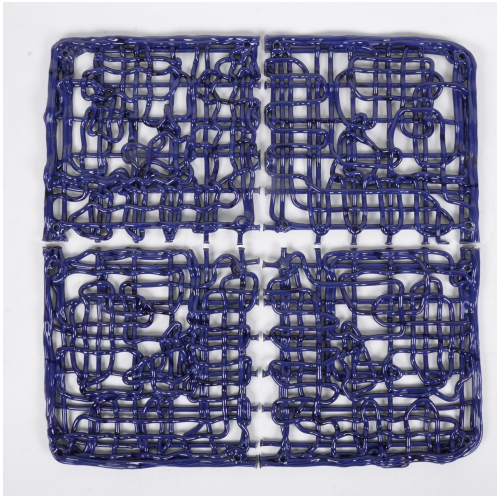


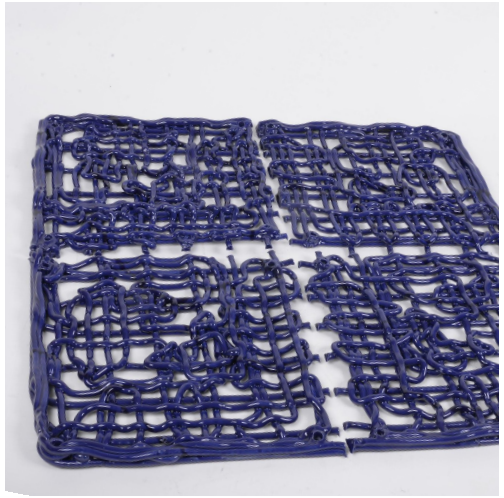




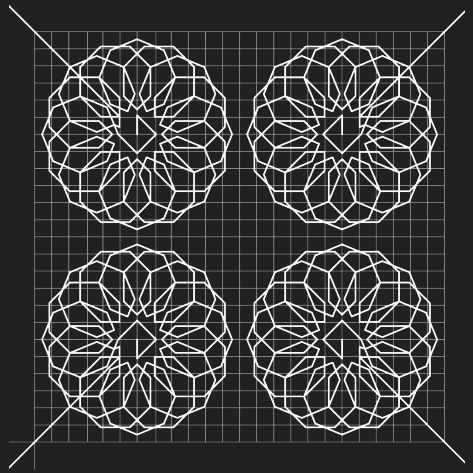
Rainscreen - 1

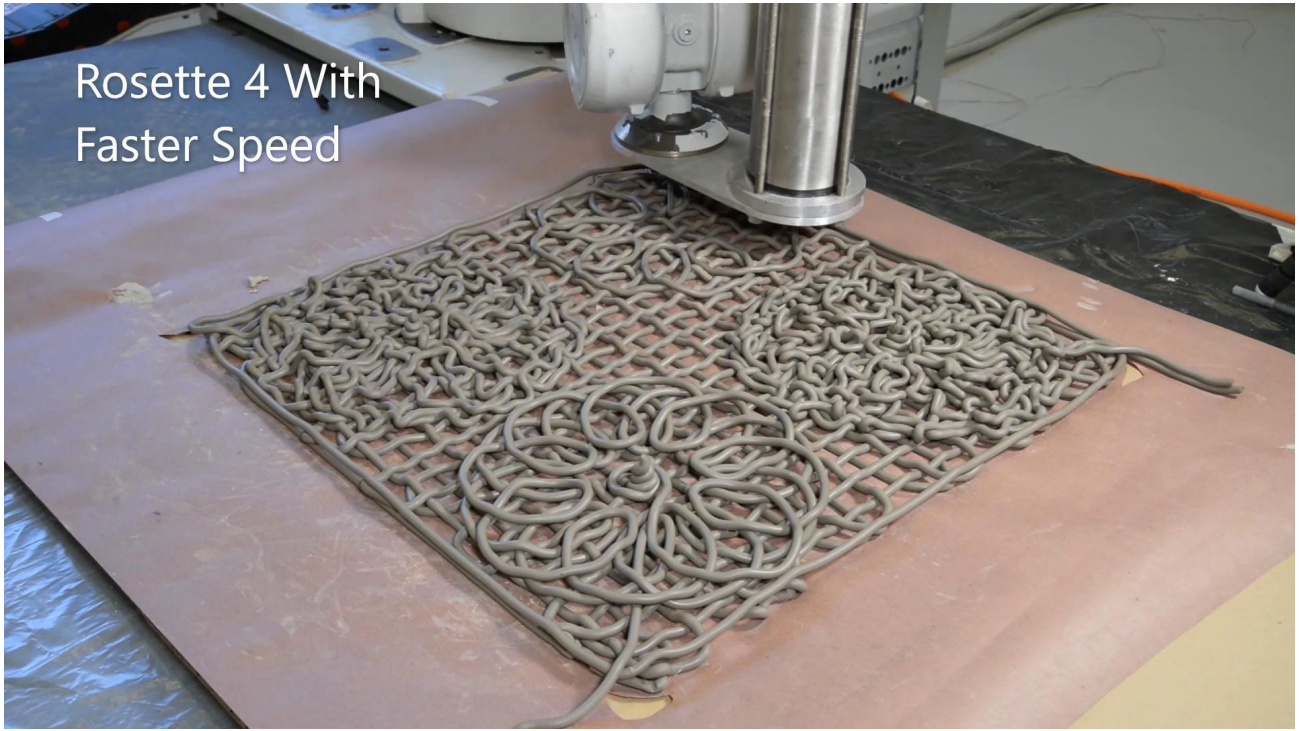




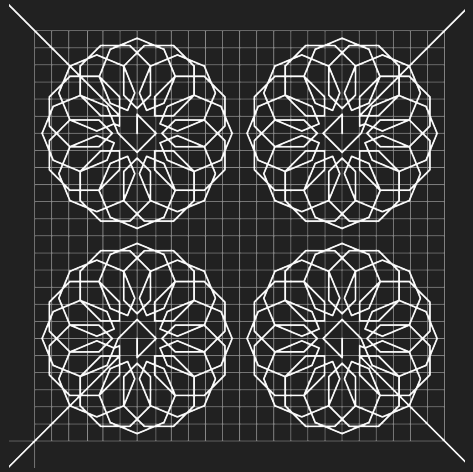


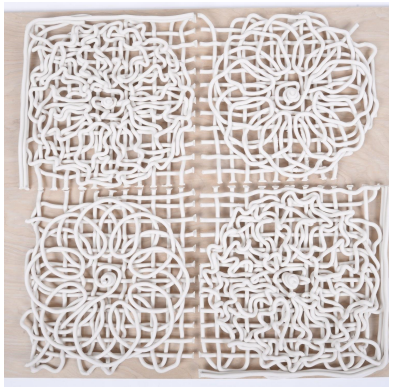
Rainscreen - 2

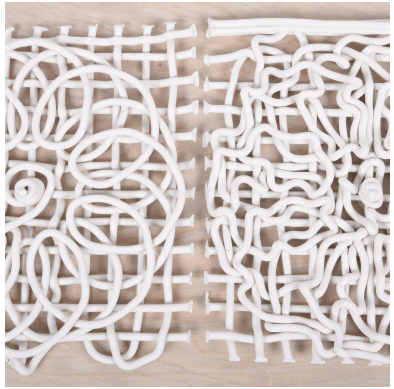




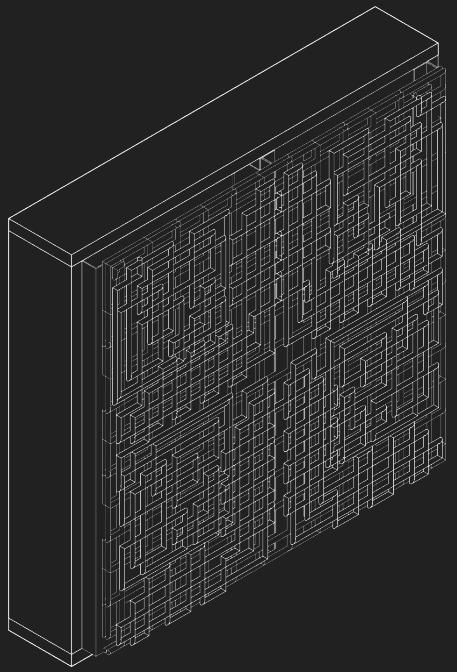
Rainscreen - 2

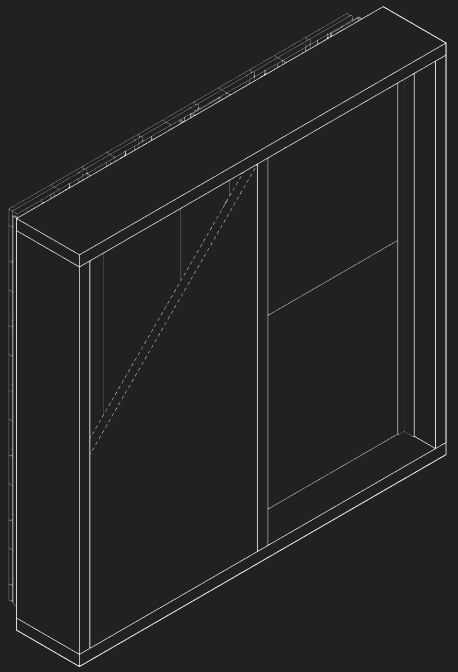






Wall Assembly:





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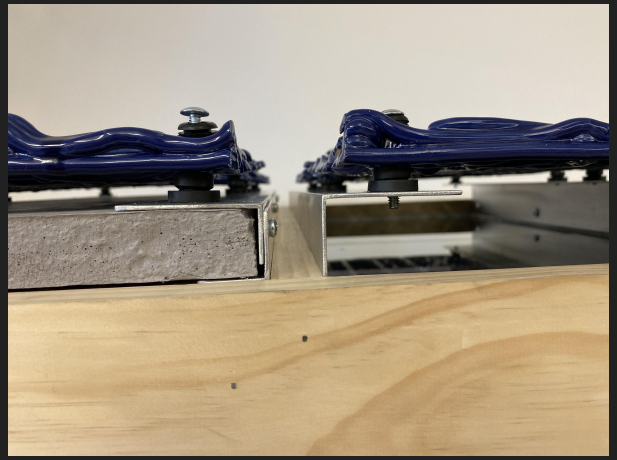

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