Research on Mycelium Construction Materials

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Introduction

Overview

This research project evaluates mycelium-based biocomposite materials for use in an architectural installation to be constructed on the UBC campus during the summer of 2015. Mycelium biocomposites typically consist of cellulosic agricultural waste bound together by mycelium, the scientific term for the web-like root structure of mushroom. These biocomposites offer the promise of achieving structural performance with minimal environmental impacts. The research establishes basic performance criteria and aesthetic qualities of mycelium biocomposites, and explores the feasibility of producing these materials locally using regional mycelium strains and substrate materials.

The mushroom biocomposites investigated use of agricultural waste as medium, and mycelium as binding agent. Mycelium is the vegetative part of fungus that grows within the agricultural waste. As mycelium fills the growth medium, it is then cooked to stop expansion. This is the base of one mycelium block. By alternating the recipe of the growth medium, the growing time, and the strength of the material can be controlled, as well as surface texture. It is a home-compostable, bio-based, renewable, biodegradable material.

The research investigates three alternatives for mushroom biocomposites:

1. Using a ready-made block available commercially through Evocative, a company located in upstate New York
2. Molding blocks or larger forms using commercially available growth kits consisting of mycelium and agricultural waste, available from the same company
3. Fabricating blocks from locally sourced mycelium strains and substrates

The research encompasses fabrication of blocks as well as design operations and material coatings. Computer aided fabrication process such as Computer Numerically Controlled (CNC) system and parametric design methodologies is to be explored. The aim is to produce a spatial condition that would enrich the social life on UBC campus while demonstrating the functional and aesthetic possibilities of mycelium-based biocomposites in our built environment.

Objectives

The research conducted to date has the following objectives

- Define the steps to create mycelium-based biocomposite blocks
- Describe the aesthetic characteristics of mycelium-based biocomposite blocks at various stages of growth and decay
- Assess the feasibility of fabricating blocks with local strains and substrate materials
- Establish the likely effect of weathering on the blocks
- Determine the best method for building with these materials and valuate the overall feasibility of constructing an installation with mycelium-based biocomposite blocks on the UBC campus

1. Mycelium Growth Experiment

We examine material manipulation enabled by recolonization of dry mycelium blocks. The following experiments involve regrowth, using mycelium as bonding medium and water resistance test.

Experiment A-1: Re-generating Growth on Ecovative Mycelium Blocks

Experiment Started on 2014-10-15
Experiment Ended on 2014-10-22

Objectives:
Examine the recolonization of mycelium and/or contamination and document the process
Devise a method to provide ideal moisture level for recolonizing the blocks with mycelium

Material Included:

3 slices from GIY block (Ecovative)
3 slices from treated blcok (Ecovative)

Moisture Contolling Factor:

(All the slices soaked in water for one day)

Set #1: Spraying water on the sponge everyday
Set #2: Spraying water on the sponge every 2 days
Set #3: Spraying water on the sponge every 3 days

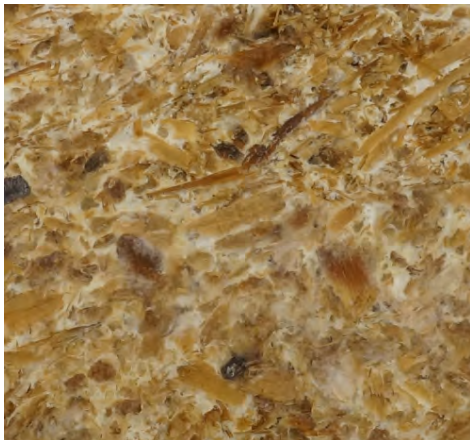
Outcomes:
There is clear development of mycelium with GIY Block which takes about less than 24 hours to be re-colonized. The Treated Block does not show sign of mycelium regrowth. In Experiment A-2, fragments from GIY block can be re-moulded and takes any kind of form as the mycelium bonds the wood chips and forms a thicker skin on the exterior.

Observation Day 1: 2014-10-16

Set #1 Procedure:

Spraying water on the sponge everyday

Sprayed



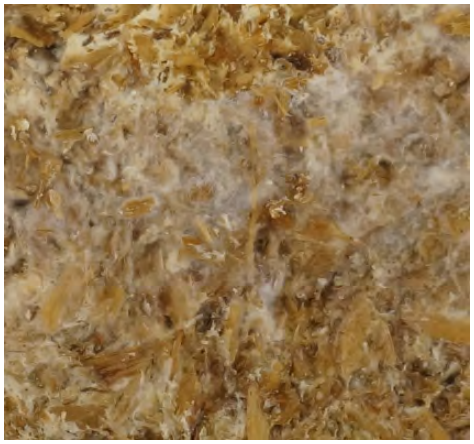
Set #1- GIY Block
Signs of fungal colonization, but less than others slices.

Set #1- Treated Block
No change visible.

Set #2 Procedure:

Spraying water on the sponge every 2 days

Sprayed



Set #2- GIY Block
Most visible signs of fungal colonization. Partial distribution of white coloration.

Set #2- Treated Block
No change visible.

Set #3 Procedure:

Spraying water on the sponge every 3 days

Sprayed

Set #3- GIY Block
Some signs of fungal colonization. Partial distribution of white coloration.

Set #3- Treated Block
No change visible.

Observation Day 2: 2014-10-17

Set #1 Procedure:

Spraying water on the sponge everyday

Sprayed

Set #1- GIY Block
Full distribution of white coloration. Some original parts visible.

Set #1- Treated Block
No change visible.

Set #2 Procedure:

Spraying water on the sponge every 2 days

Not Sprayed

Set #2- GIY Block
Full distribution of white coloration. Seems thicker layer of distrubution than others.

Set #2- Treated Block
Visible signs of Cobweb mold contamination about 30% of the surface.

Set #3 Procedure:

Spraying water on the sponge every 3 days

Not Sprayed

Set #3- GIY Block
Full distribution of white coloration. Fairly covers the surface.

Set #3- Treated Block
Visible signs of Cobweb mold contamination about 10% of the surface.

Observation Day 3: 2014-10-18

Set #1 Procedure:

Spraying water on the sponge everyday

Sprayed

Set #1- GIY Block
Full distribution of white coloration. No contamination detected. Still reveals some part of the surface.

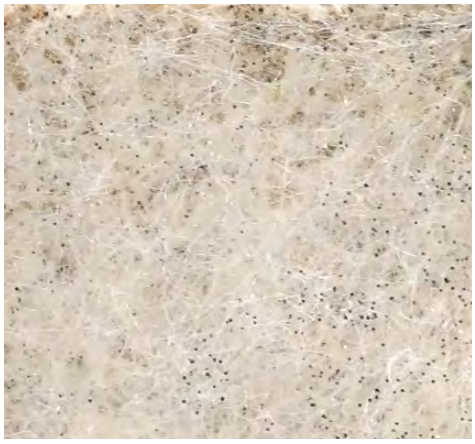
Set #1- Treated Block
No change visible.

Set #2 Procedure:

Spraying water on the sponge every 2 days

Sprayed

Set #2- GIY Block
Full distribution of white coloration. No contamination detected. Still thickers than others.



Set #2- Treated Block
Visible signs of Cobweb mold contamination 100% of the surface. Balck heads appear.

Set #3 Procedure:

Spraying water on the sponge every 3 days

Not Sprayed

Set #3- GIY Block
Full distribution of white coloration. No contamination detected.

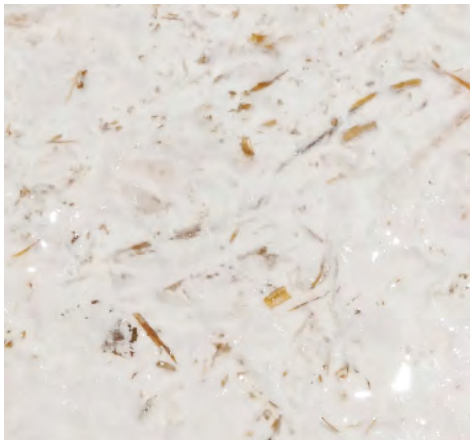
Set #3- Treated Block
Visible signs of Cobweb mold contamination about 50% of the surface. Balck heads appear.

Observation Day 4: 2014-10-19

Set #1 Procedure:

Spraying water on the sponge everyday

Sprayed



Set #1- GIY Block
Full distribution of white coloration. No contamination detected.

Set #1- Treated Block
Visible signs of Cobweb mold contamination about 5% of the surface.

Set #2 Procedure:

Spraying water on the sponge every 2 days

Not Sprayed

Set #2- GIY Block
Full distribution of white coloration. No contamination detected.

Set #2- Treated Block
Visible signs of Cobweb mold contamination all around the surfaces.

Set #3 Procedure:

Spraying water on the sponge every 3 days

Sprayed

Set #3- GIY Block
Full distribution of white coloration. No contamination detected.

Set #3- Treated Block
Visible signs of Cobweb mold contamination all around the surfaces.

Experiment A-2: Examination of Surface after Re-growth Experimentation

Note: The GIY Slice Set #1 was dried and the surface is documented.

GIY Slice Set #1

(Day 1)

Dried GIY Slice Set #1

(Day 15)

The GIY Slice Set #1 from Experiment A has been dried for surface observation. The entire surfaces are covered with newly colonised mycelium, and some part - especially the top part of the slice - seems to have had contamination with grey spots.

Experiment A-3: Continuation of Re-growth Experimentation

Note: The GIY Slice Set #2 was covered with ziplock bag and the surface is documented.
In the course of the experiment, the slice is exposed to natural sun light.

GIY Slice Set #2

(Day 1)

The GIY Slice Set #2 from Experiment A has been sprayed everyday for a week in the beginning. And then it was sprayed every 3-4 days to control the humidity. It was contained in a ziplock bag with plastic container and a sponge and the water was sprayed onto the sponge.

After the Experiment A, a blob that is about 8mm in diameter on the ziplock bag surface is observed. It seems to move along the plastic surface.

At Day 24, the blob has been transforming and growing a new surface, and the previous one has changed the colour to yellow.

Growing Continued GIY Slice Set #2

(Day 20)

(Day 24)

(Day 27)

Note: The GIY Slice Set #3 stays in the same condition and the surface is documented.
In the course of the experiment, the slice is exposed to natural sun light.

GIY Slice Set #3

(Day 1)

The GIY Slice Set #3 from Experiment A has been sprayed everyday for a week in the beginning. And then it was sprayed every 3-4 days to control the humidity. It was contained in plastic container with a sponge and the water was sprayed onto the sponge.

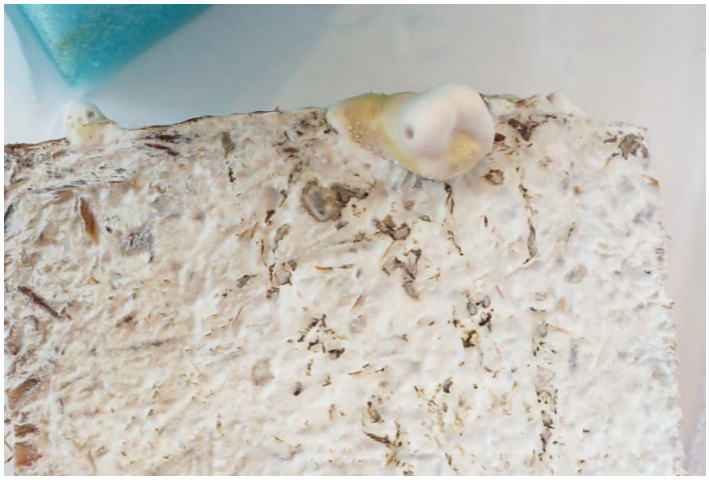
After the Experiment A, a blob that is about 10mm in diameter on the myselium surface is observed. The surface of the blob seems to be condensed myselium or some sort.

At Day 24, the blob has been transforming and growing a new surface, and the previous one has changed the colour to yellow.

Growing Continued GIY Slice Set #3

(Day 20)

(Day 24)



(Day 27)

Note: The nagative part of the Chair Series #2 from GIY was put into a plastic bag and the surface is documented. In the course of the experiment, the slice was not exposed to natural sun light.

Nagative Part of Chair Series #2

(Before the Experiment)

This negative part of Chair Series #2 from GIY block has been sprayed everyday until Day 7. The plastic bag was not completely sealed so that there is air flowing.

At Day 3, condensation on the myselium surface is observed. The whole piece seems to be covered with mycelium.

At Day 7, there seem to be symptoms of contamination with molds around the grey spots. However the molds seem to grow on the side where it is open to the air rather than on the surface that is touching the plastic bag.

(Day 1)

(Day 3)

(Day 7)

GIY Slice Set #2: Surface Observation after Drying
With both GIY Slice set #2 and #3, there is clear shrinkage after a long period of time of drying.

GIY Slice Set #3: Surface Observation after Drying

Nagative Part of Chair Series #2: Surface Observation after Drying

Experiment B-1: Continuation of Re-growth Experimentation with Saw Dust

Note: The saw dust from cutting with band saw was put into a ziplock bag and the surface is documented. In the course of the experiment, the saw dust was not exposed to natural sun light.

Saw Dust Bag #1

(Before the Experiment)

This bag of saw dust from GIY block has been sprayed everyday until Day 7. It was realised that the humidity level was too high as the speed of colonisation was relatively slow.

Since Day 7, it was sprayed very occasionally by observation (only when there was no high percentage of condensation). And the sealed ziplock bag was open to allow more air.

At Day 25, the saw dust is completely colonised and the powder is bonded with healthy mycelium.

(Day 1)

(Day 3)

(Day 7)

Note: The saw dust from cutting with band saw was put into a ziplock bag and the surface is documented. In the course of the experiment, the saw dust was not exposed to natural sun light.

Saw Dust Bag #2

(Before the Experiment)

This bag of saw dust from GIY block has been sprayed every 3days until Day 7. It was realised that the humidity level was too high as the speed of colonisation was relatively slow.

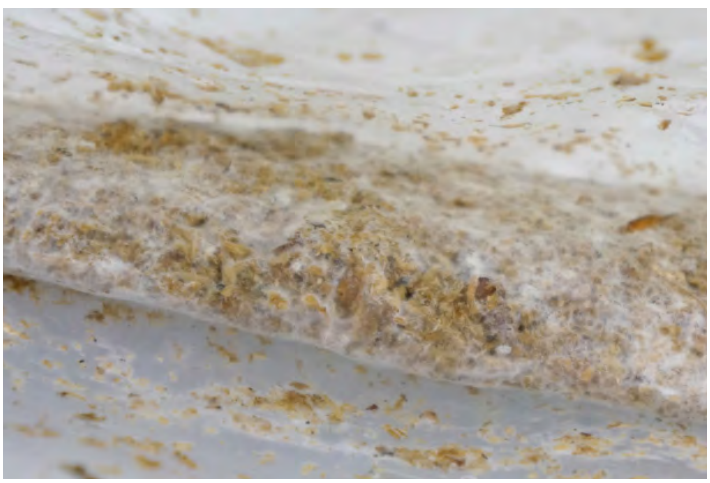
Since Day 7, it was sprayed very occasionally by observation (only when there was no high percentage of condensation). And the sealed ziplock bag was open to allow more air.

At Day 25, the saw dust is completely colonised and the powder is bonded with mycelium as well as symptoms of contamination with molds. However the molds seem to grow on the side where it is open to the air rather than on the surface that is touching the ziplock bag.

(Day 1)

(Day 3)

(Day 7)



Saw Dust Bag #1: Surface Observation after Drying
The saw dust is completely covered with a thick layer of mycelium.

Saw Dust Bag #2: Surface Observation after Drying

Experiment B-2: Conneting Mycelium Blocks

Note: Two pieces of GIY slices were put into a ziplock bag and the capability of mycelium as bonding material. The same re-colonization process has been applied to allow mycelium's growth.

The two GIY Slices were moisturized and kept in a ziplock bag for seven days to reactivate the mycelium colonization. After the mycelium was re-colonized the two pieces are bonded together. It is evident no external adhesive is required to put two pieces together.

Experiment C: Water Dripping Friction Test

Experiment Started on 2014-10-21
Experiment Ended on 2014-10-22

Objectives:
Find out how the block mass can stand against water impact.

Material Included:

1 slice from treated block (Ecovative)

Water Impact Contolling Factor:

Set #1: Water dripping 3L/1hr for 12 hours
Set #2: Water dripping 27L/1hr for 1 hour

Outcomes:
Material does not disintegrate due to the moisture, but physical impact. The degree of physical impact makes difference in terms of the material subtraction.

Set #1

5mm radius
3mm deep

3L/hr for 12hr

Set #2

8mm radius
7mm deep

27L/hr for 1 hr

2.
Mycelium Block Surface Documentation

As part of the material research, this section documents the surface texture under different methods of tooling. From surface that is milled by CNC to the ones that have been re-colonized, this document explores possible ways to integrate a variety of texture for the installation project.

Band Saw Cut Piece from GIY Block (g-1)

CNC Cut from Treated Block (t-1)

CNC Cut from Treated Block (t-2)

CNC Cut from Treated Block (t-2)

CNC Cut from GIY Block (g-2)

CNC Cut from GIY Block (g-2)

CNC Cut from GIY Block (g-3)

CNC Cut from GIY Block (g-3)

CNC Cut from GIY Block (g-3)

CNC Cut from GIY Block (g-3)

Band Saw Cut from GIY Block (g-4)

Band Saw Cut from GIY Block (g-4)

Band Saw Cut from GIY Block (g-4)

Band Saw Cut from GIY Block (g-5)

Band Saw Cut from GIY Block (g-5)

Band Saw Cut from GIY Block (g-5)

Band Saw Cut from GIY Block (g-5)

Band Saw Cut from GIY Block (g-6)

Band Saw Cut from GIY Block (g-6)

Band Saw Cut from GIY Block (g-7)

Treated Block Teared by Hand (t-3)

Treated Block Teared by Hand (t-3)

Treated Block Teared by Hand (t-4)

Band Saw Cut from Treated Block (t-5)

Treated Block from Ecovative (t-6)

Treated Block from Ecovative (t-6)

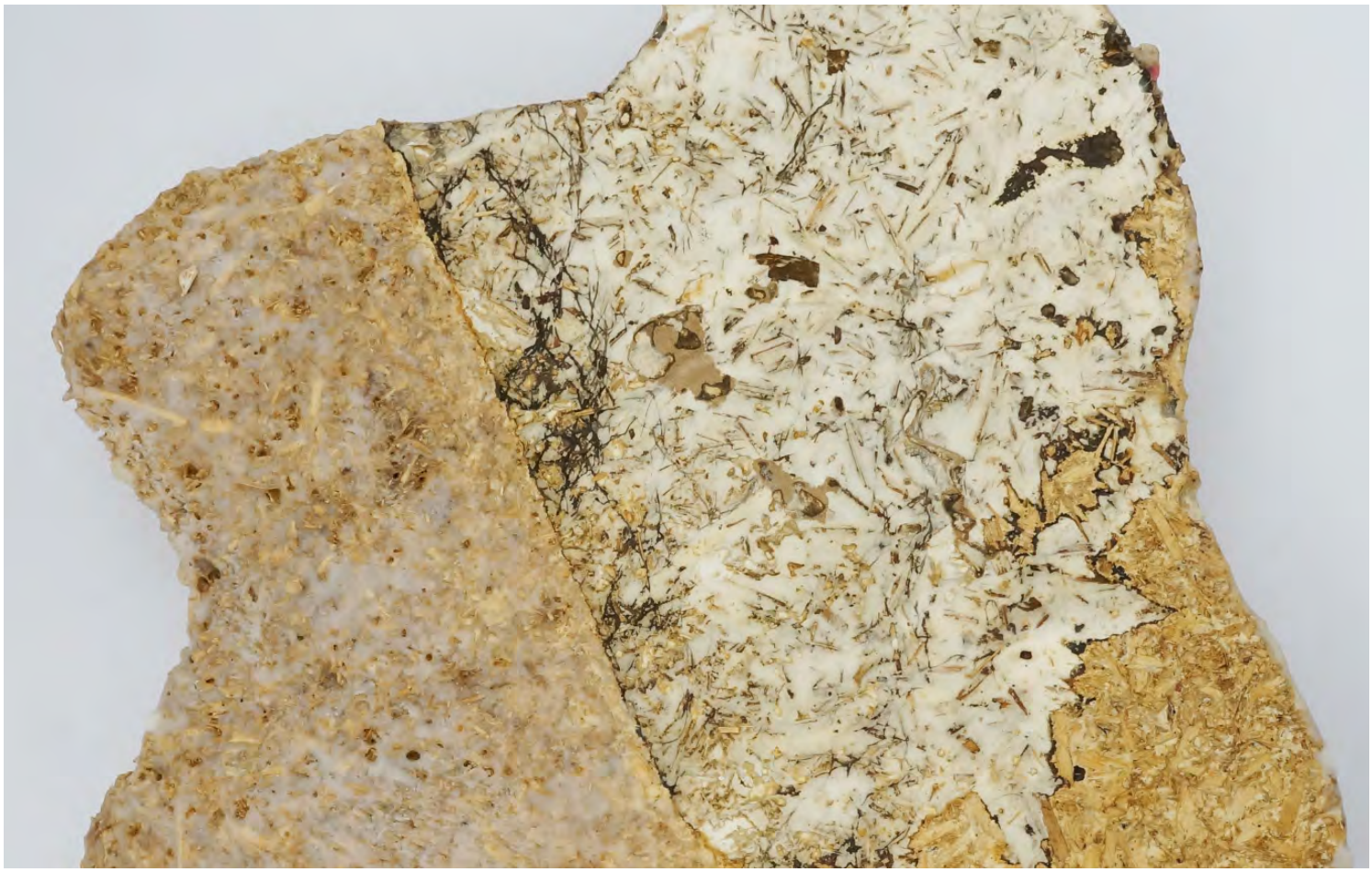
Treated Block from Ecovative (t-6)

3.
Mycelium Chair Series Documentation

The form of chair provides haptic experience with the mycelium building material. In this section, there are three different forms that were cut and coated with non-toxic materials such as white glue and natural wax.

Chair Series #1
Bank Saw cut with white glue coating

Chair Series #2
CNC cut with white glue coating and soy wax



Chair Series #2
CNC cut with white glue coating and soy wax

Chair Series #3
CNC cut with white glue coating

Chair Series #3
CNC cut with white glue coating


X
Y
3,3

4.
Local Mycelium

The blocks here were made from mushrooms available in Vancouver: Oyster mushroom and Shiitake. This documents the process of moulding them and the blocks after drying.

Shiitake Mushroom

Shiitake mushroom was already fruiting before the process of moulding has begun. The image at the bottom is taken while the moulding was just initiated. Shiitake has distinctive texture and colour compared to Oyster mushroom

The image above is the day 1 after the putting into the container for moulding. After 7 days of re-colonization, the block is dried for 10 days. There is clear evidence of contamination with molds where the green and black spots are. Shiitake mushroom appears to be more brittle and easy to break even after drying.

Oyster Mushroom

After purchsed in a bag, the mushroom spore with substrate has been re-moulded in a plastic container. The mycelium of Oyster mushroom appears similar to the one with Ecovative.

The image on top shows the block dried for 10 days after 7 days of re-colonization. There is no contamination with mold, and the growth of mycelium seems clear. Oyster mushroom's mycelium appears identical to the one with Ecovative. Interesting texture remains on top where it was exposed to air inside the moulding container.

Oyster Mushroom Block Samples


GP B <Brick
GROW Jan 24
DRY Feb 12


GP B (Brick)
Grow Jan 24
DRY extended


GP A (Brick)
GROW: Jan 24
DRY: Feb 3

Discussion & Future Work

The research conducted to date has shown that it is feasible to build a temporary installation with mycelium based biocomposites on the UBC campus. Preliminary findings indicate that is should be possible to fabricate blocks locally using regional strains and materials. This route will require physical infrastructure as follows:

- Contamination-controlled enclosed workspace of 300SF with stable temperature.
- Incubation and drying space of 200 SF.
- Access to steam pressure cooker or autoclave for sterilization of substrate materials prior to inoculation.
- Vacuum forming equipment for molds.

In addition to the physical requirements above, additional materials research must be conducted in the following areas:

- Identify local source of substrate (local agricultural waste such as sawdust or straw).
- The growing process can take up to 20 days depending of fungi species. For this reason, space we need has to be available for an extensive amount of time.
- Local mycological expertise to match strain to substrate and to address unanticipated future concerns.

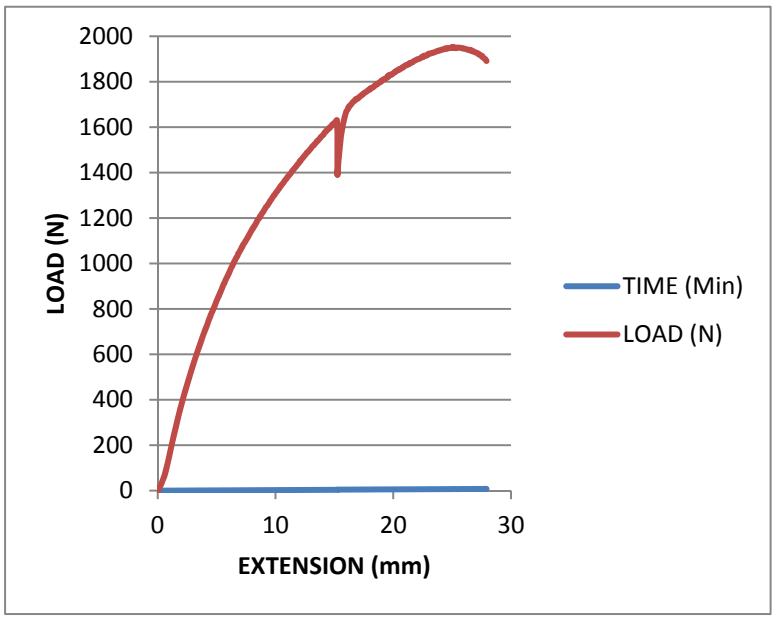
Conclusion

Mycelium biocomposites offer the promise of achieving structural performance with minimal environmental impacts. The research establishes basic performance criteria and aesthetic qualities of mycelium biocomposites, and determines that producing these materials locally using regional mycelium strains and substrate materials is feasible. The research finds that the organic structure of mushroom mycelium can be used as self-assembling binding agent. Mycelium as building construction material is a new area in building technology. Despite the limited information available, we found that we can successfully fabricate mycelium blocks using regional materials. Although the initial findings are promising, additional research will be required to determine appropriate match of local mycelium strains and substrates, and physical infrastructure will be necessary.

5.
Compression Test

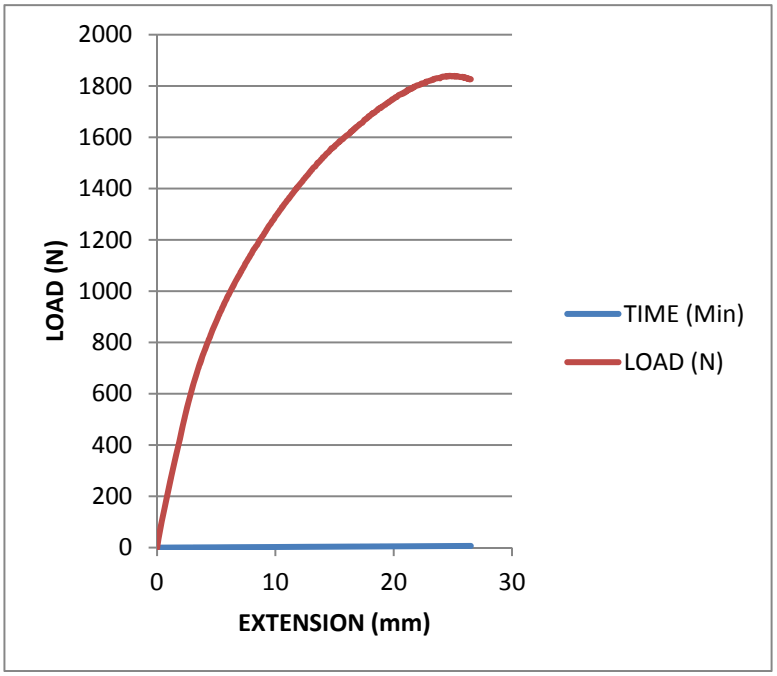
Compression tests are performed to determine the structural performance of mycelium blocks. Each specimen is cylinder that is approximately 4 inch in diameter and 8 inch in height.

Cylinder #1



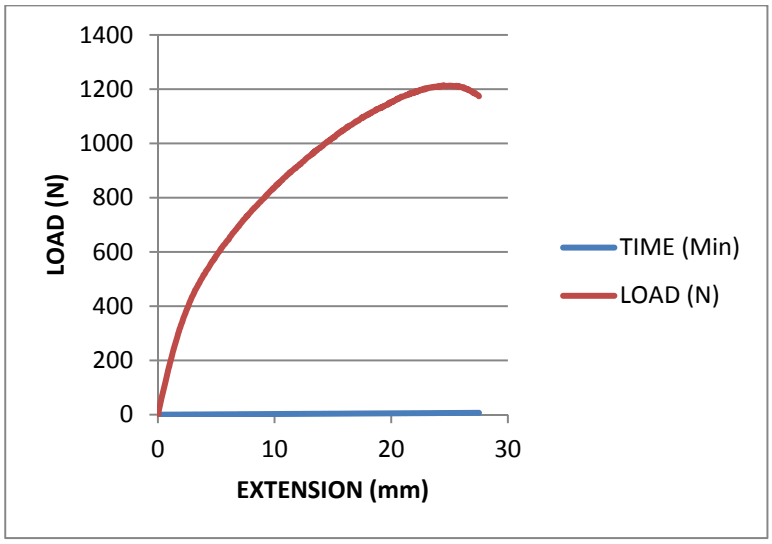
EXTENSION (mm)	TIME (Min)	Weight(g)	d(mm)	area(mm2)	peak load(N)	N/mm2	PSI	Mpa
27.9	7.7	264	95	7088.22	1953.1	0.2755	39.9639	0.2755

Cylinder #2



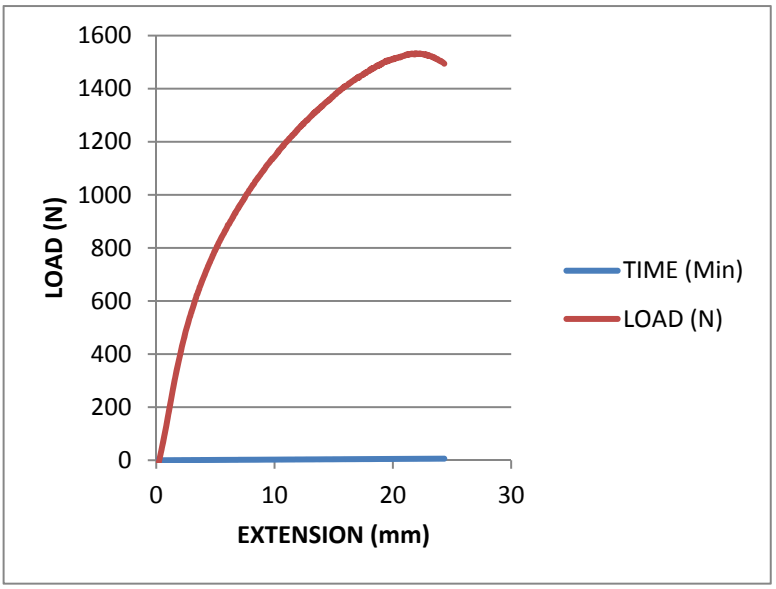
EXTENSION (mm)	TIME (Min)	Weight(g)	d(mm)	area(mm2)	peak load(N)	N/mm2	PSI	Mpa
26.5	6.6	270	95	7088.22	1839.9	0.259572	37.6477	0.2596

Cylinder #3



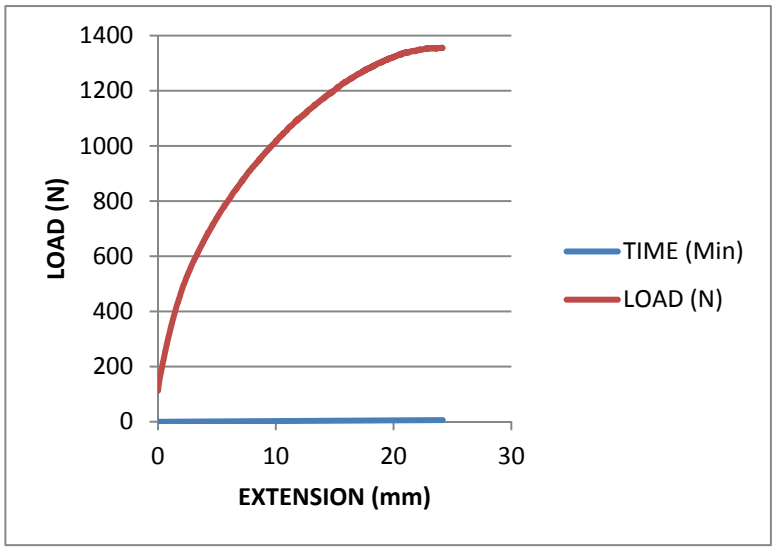
EXTENSION (mm)	TIME (Min)	Weight(g)	d(mm)	area(mm2)	peak load(N)	N/mm2	PSI	Mpa
27.5	6.9	248	95	7088.22	1213.9	0.171256	24.8386	0.1713

Cylinder #4



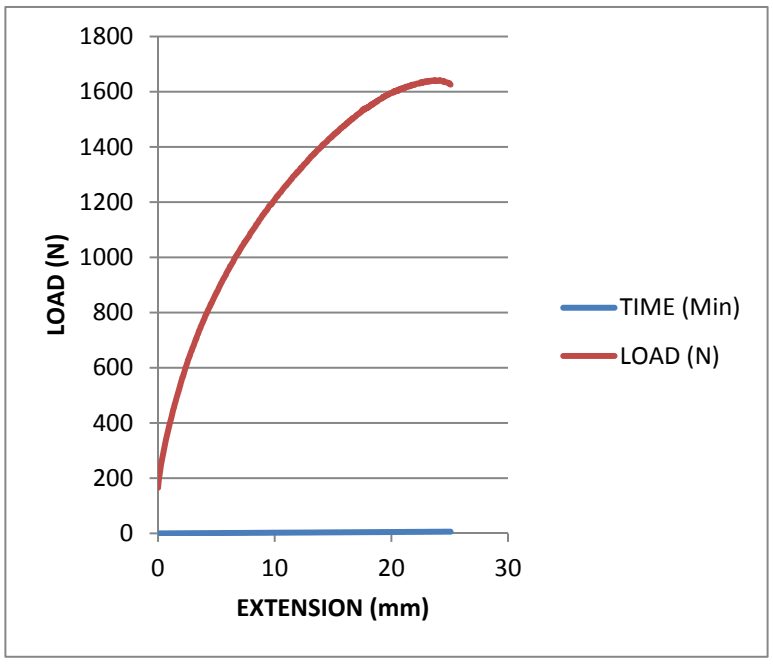
EXTENSION (mm)	TIME (Min)	Weight(g)	d(mm)	area(mm2)	peak load(N)	N/mm2	PSI	Mpa
24.3	6.1	259	95	7088.22	1532.8	0.216246	31.3639	0.2162

Cylinder #5



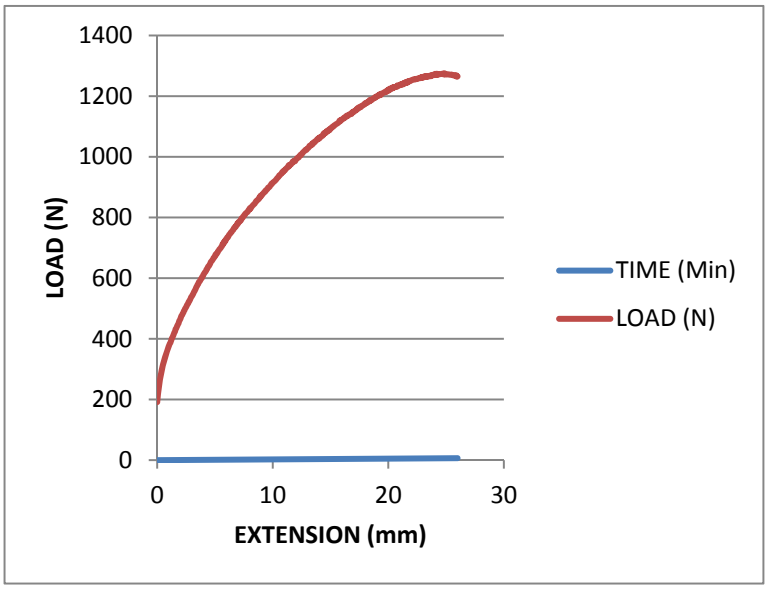
EXTENSION (mm)	TIME (Min)	Weight(g)	d(mm)	area(mm2)	peak load(N)	N/mm2	PSI	Mpa
24.2	6.1	252	95	7088.22	1356.4	0.19136	27.7544	0.1914

Cylinder #6



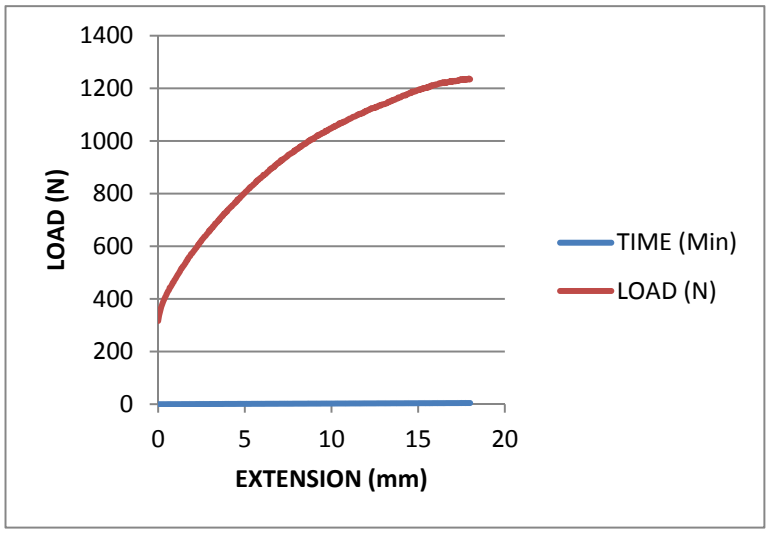
EXTENSION (mm)	TIME (Min)	Weight(g)	d(mm)	area(mm2)	peak load(N)	N/mm2	PSI	Mpa
25.1	6.3	272	95	7088.22	1642.2	0.23168	33.6024	0.2317

Cylinder #7



EXTENSION (mm)	TIME (Min)	Weight(g)	d(mm)	area(mm2)	peak load(N)	N/mm2	PSI	Mpa
26	6.5	259	95	7088.22	1275.4	0.179932	26.097	0.1799

Cylinder #8



EXTENSION (mm)	TIME (Min)	Weight(g)	d(mm)	area(mm2)	peak load(N)	N/mm2	PSI	Mpa
18	4.5	277	95	7088.22	1237.3	0.174557	25.3174	0.1746

RESULT:

Average Compression Strength	0.2125	N/mm2	30.8232	PSI	21668.97	kgf/m2
Average Unit Weight	262.625	g				
w/ safety accounted	0.0708	N/mm2	10.2744	PSI	7222.99	kgf/m2

Conclusion

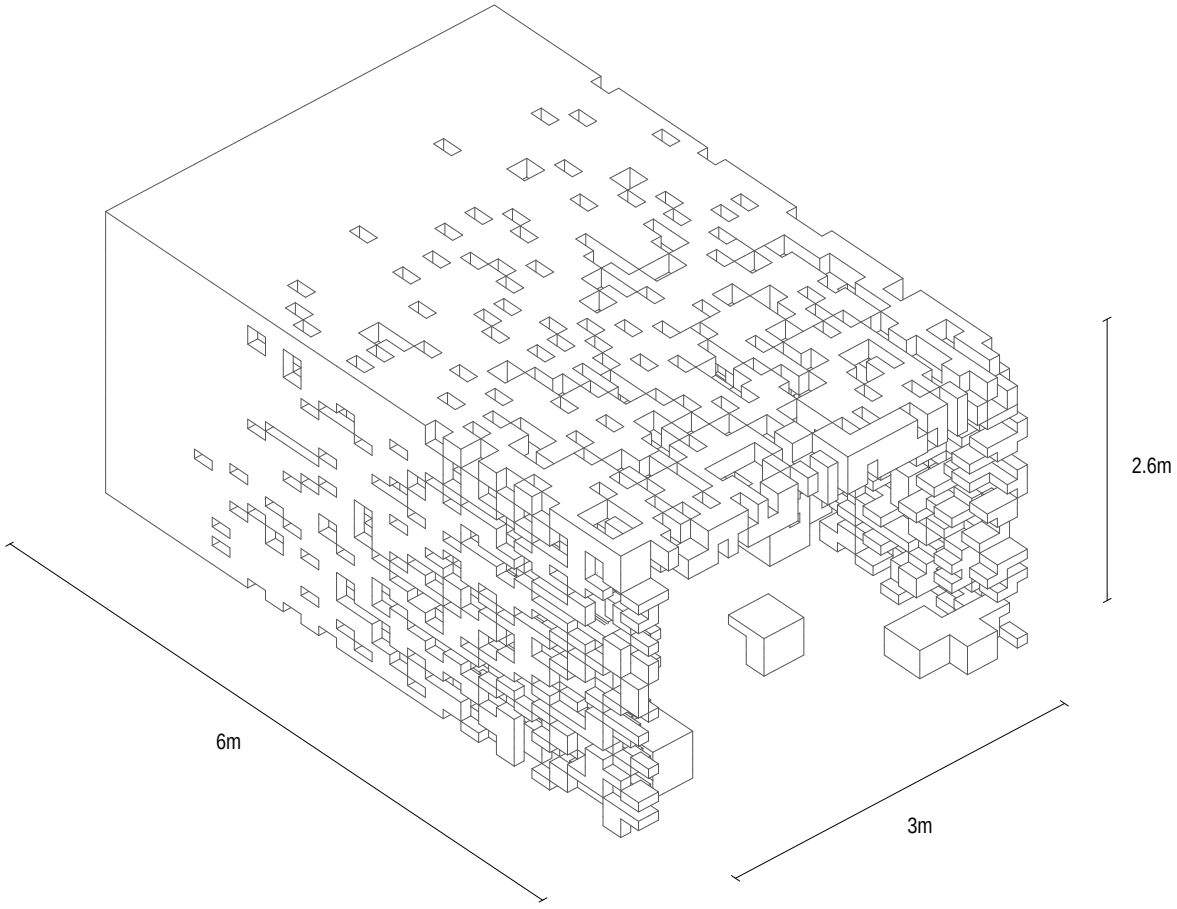
Mycelium blocks produced under our current method yield in average 10 PSI in compressive strength. In comparison, XPS foam typically has a compressive strength of 10-25 psi. This is by far the most successful batch of samples recolonized by using ready-made mushroom kit. These samples typically have thick cell walls with a cream color appearance covering the exterior of the sample surface. The thickening of the “skin” is a self protective mechanism to prevent moisture loss under warm temperature.

6.
Concept Design I

We began the design process by looking at multiple sites on UBC campus. Multiple scenarios have been taken into consideration.

Concept Design Option 1

1. Perforated Room
2. Mushroom Cloud
3. Mushroom Open House
4. Mushroom Chair



Rendering #1: Entrance area of Buchanan Building

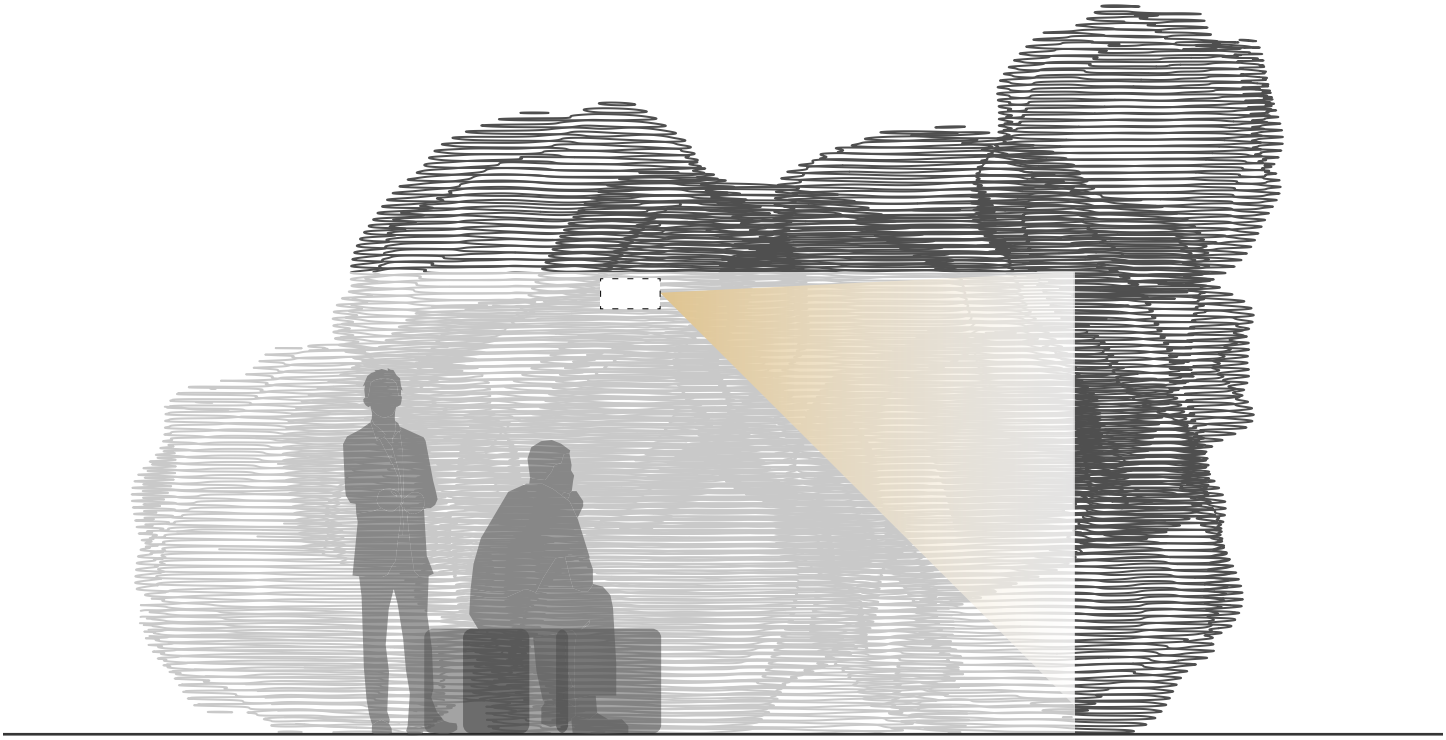
Rendering #2: Interior view of the space

Concept Design Option 2

1. Perforated Room
2. Mushroom Cloud
3. Mushroom Open House
4. Mushroom Chair

Plan

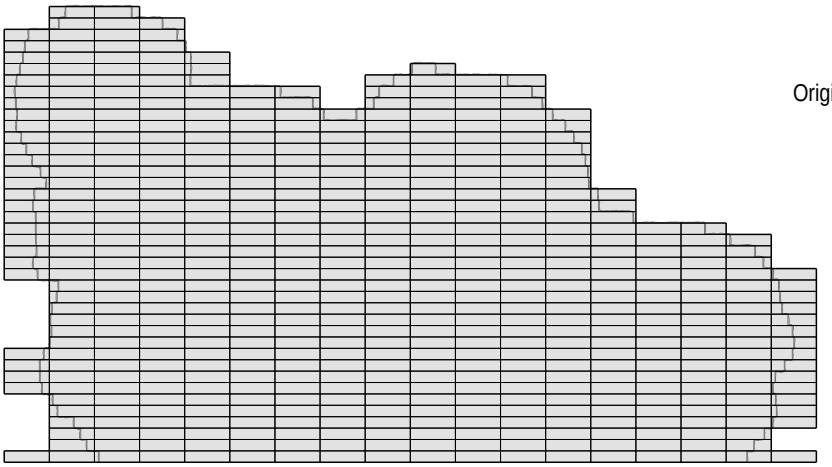
Longitudinal Section



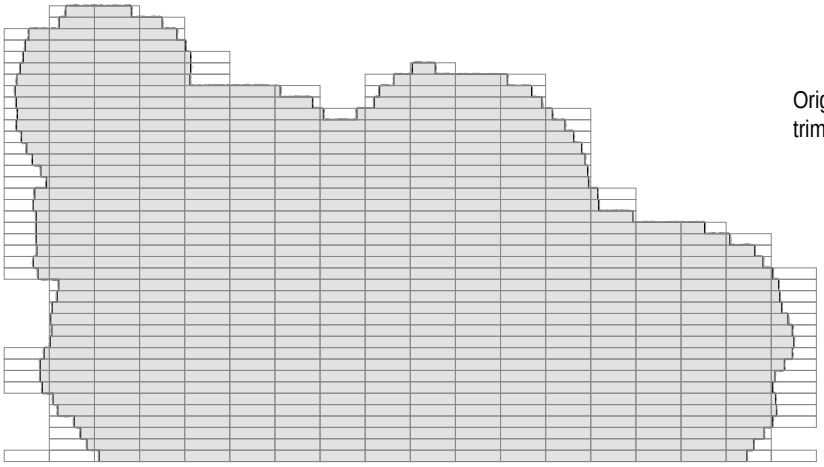
Cross Section

Mushroom cloud form study elevation view

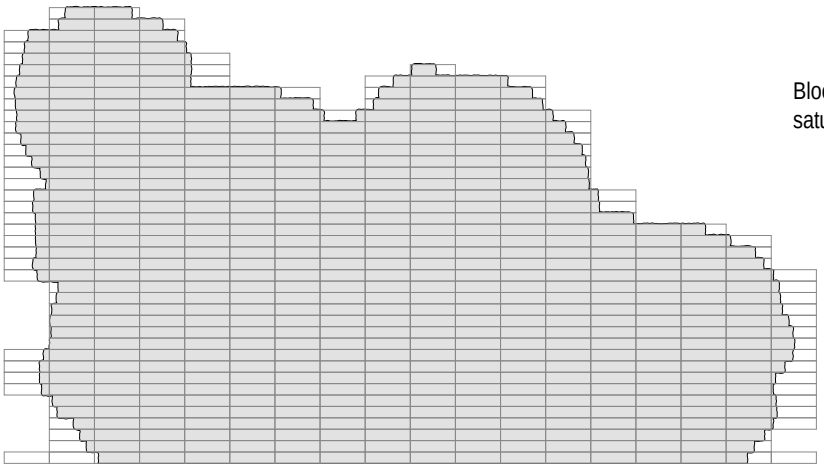
Mushroom cloud form study perspective view



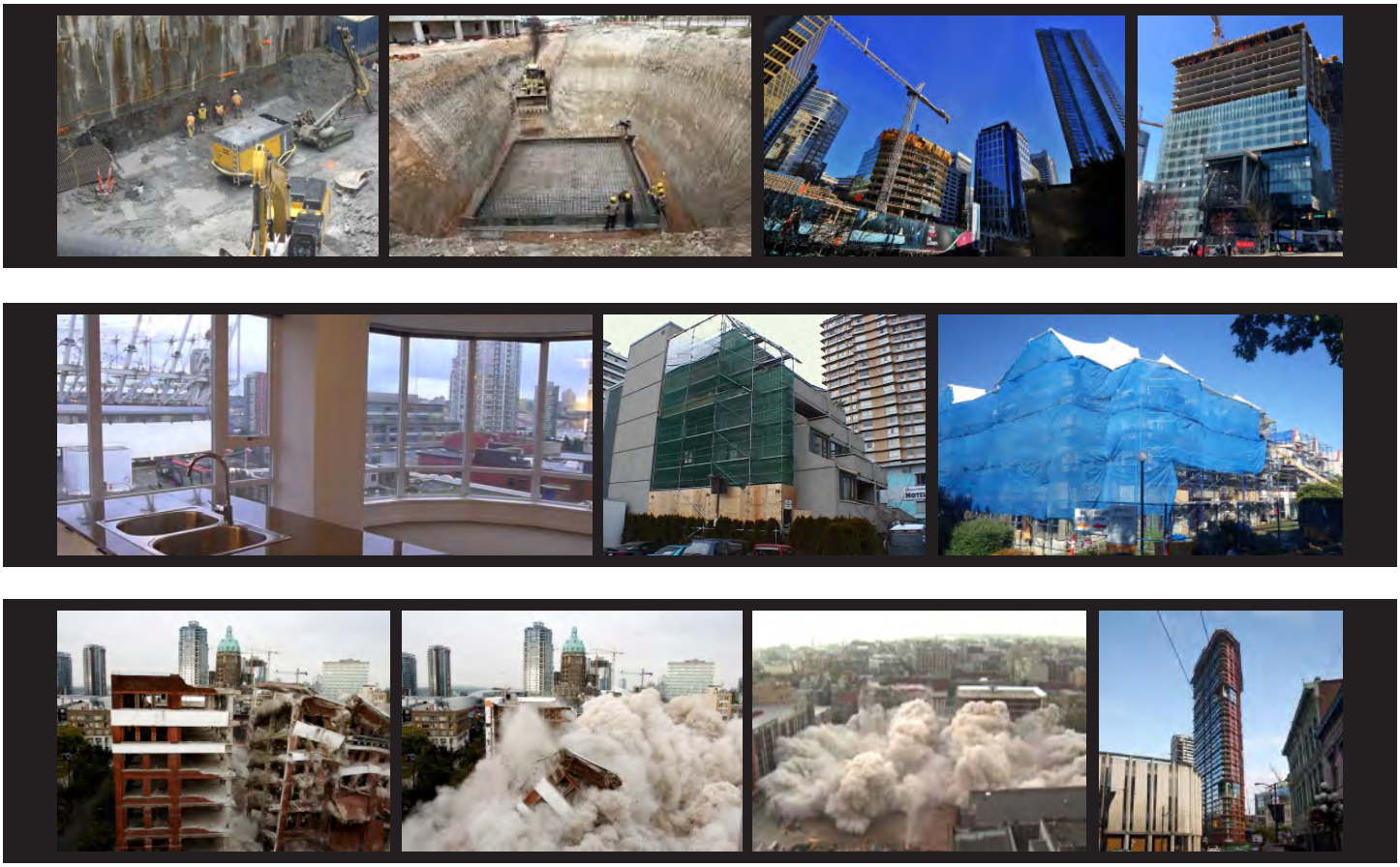
Original blocks



Original blocks
trimmed



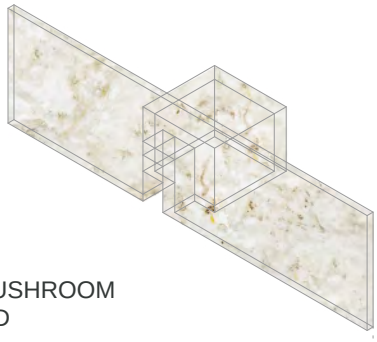
Blocks with mycelium
saturated surface



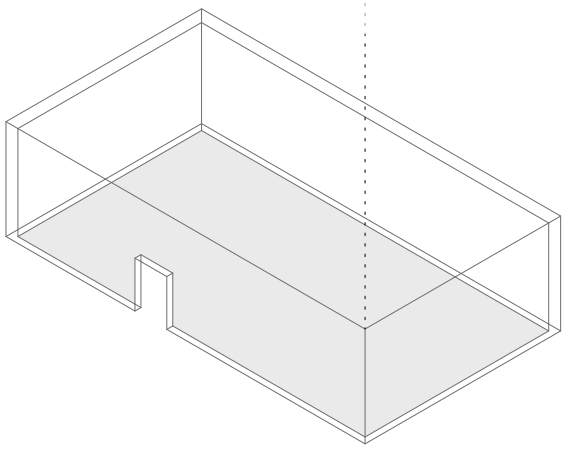
Time, Construction, Life Cycle of Buildings, Demolition, Material

Concept Design Option 3

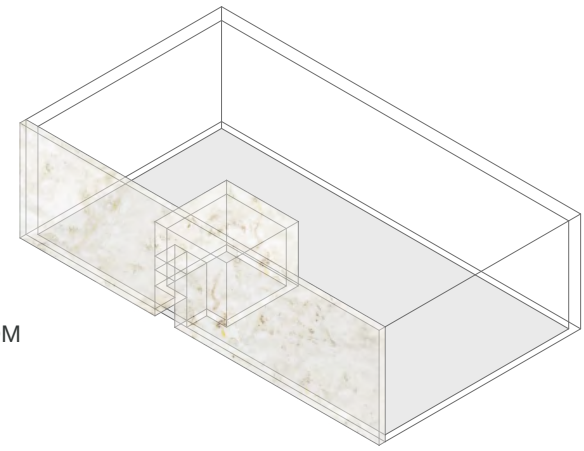
1. Perforated Room
2. Mushroom Cloud
3. Mushroom Open House
4. Mushroom Chair



MUSHROOM FACADE WITH A MUSHROOM SCREENING ROOM CONNECTED



ABANDONED BUILDING BEFORE THE DEMOLITION PROCESS

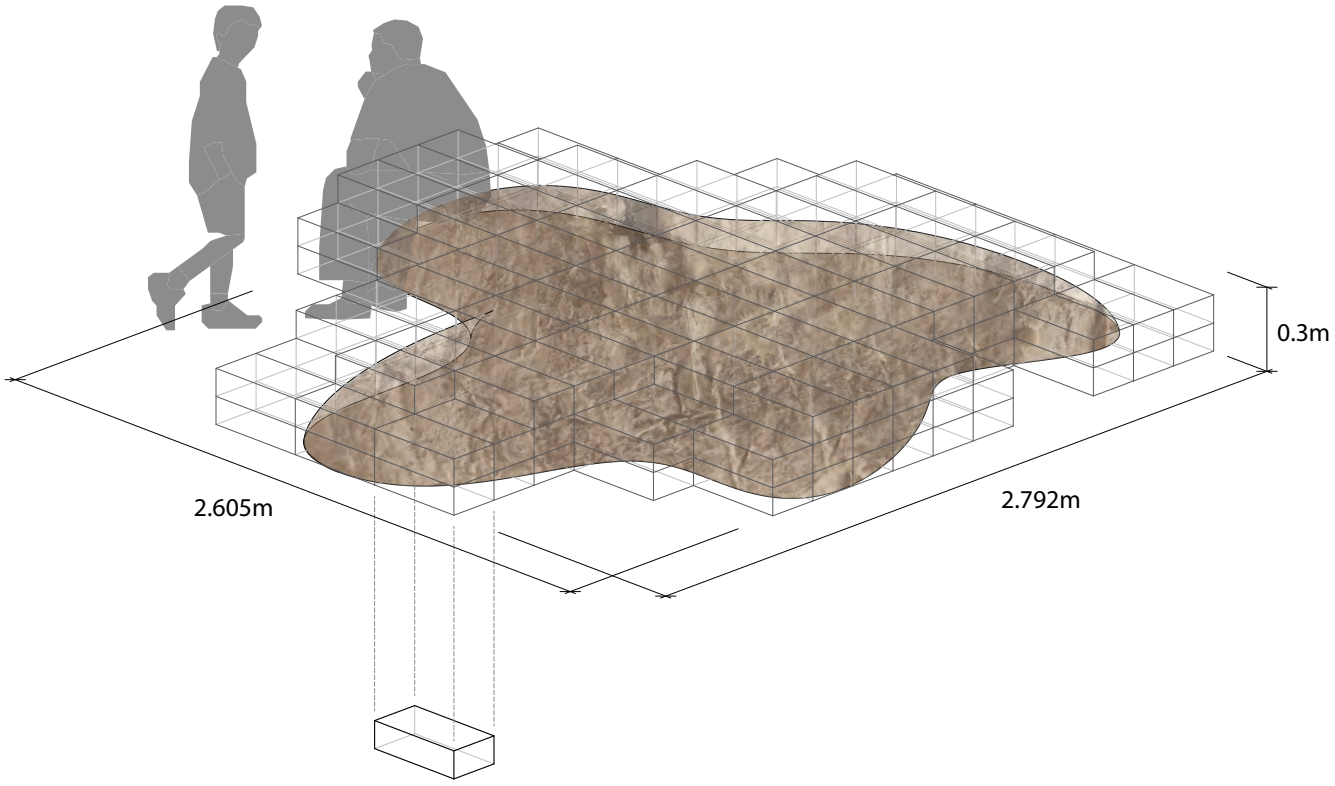


TEMPORARY SCREENING ROOM INSIDE THE BUILDING

Rendering: Interior view of the space

Concept Design Option 4

1. Perforated Room
2. Mushroom Cloud
3. Mushroom Open House
4. Mushroom Chair



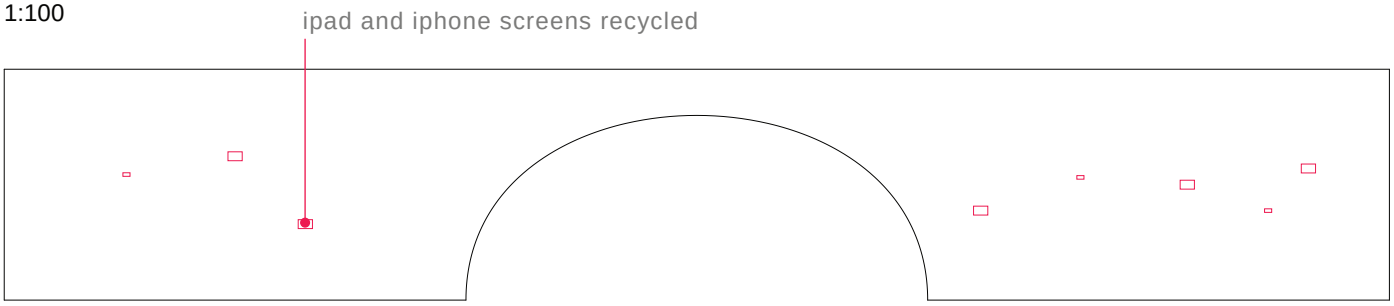
209 pieces of
400mm x 175mm x 100 mm
blocks

7.
Concept Design II

The current site is located at the intersection of University Boulevard and Main Mall. We propose to integrate the organic mushroom wall and digital displays to create a tangible experience going through the outdoor installation.

OPTION 1

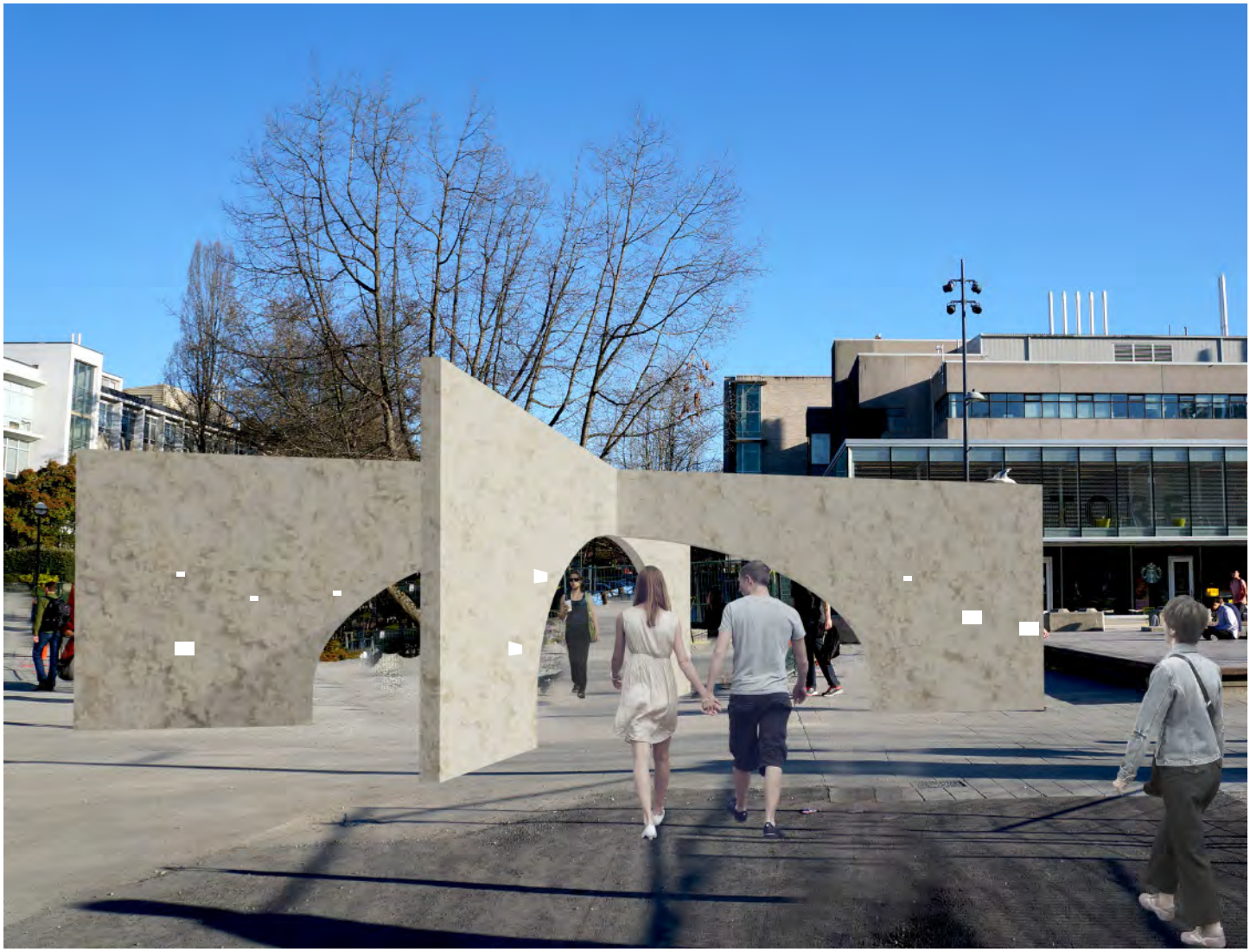
Plan
1:100

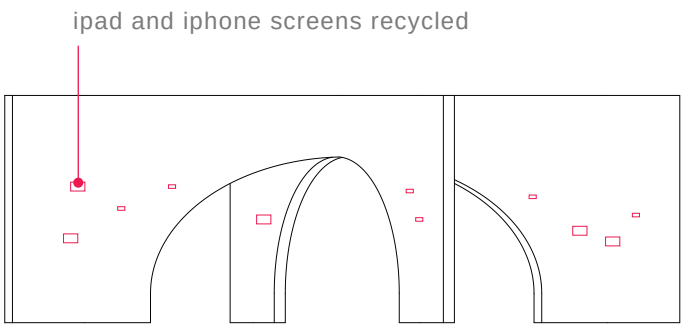


Elevation
1:100

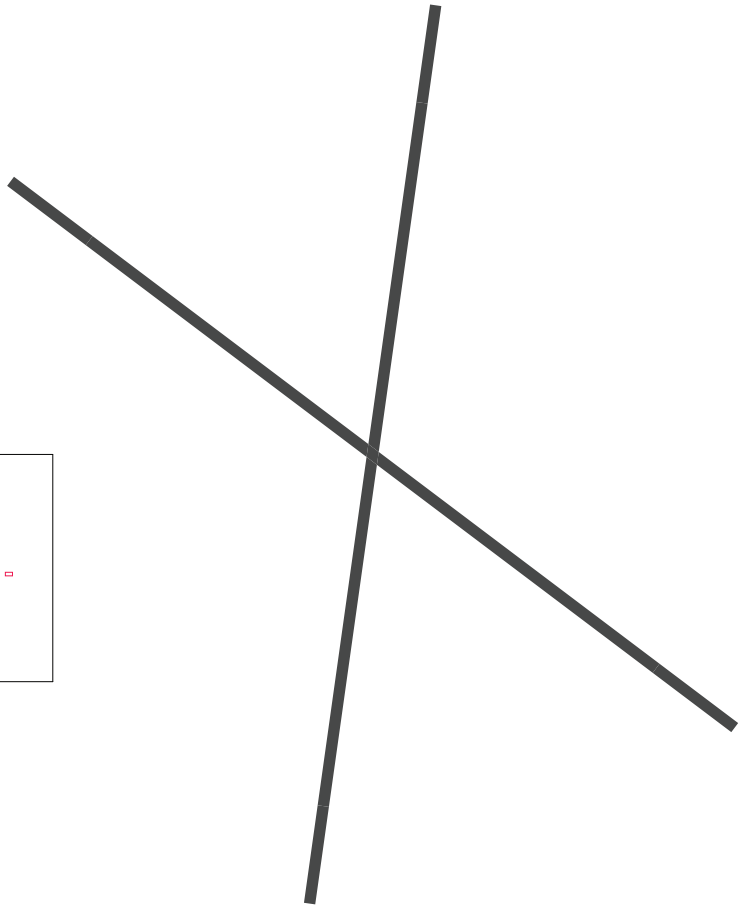
- 3m tall, 30cm thick wall
- Arch form in plan
- Concept of threshold
- Larger surface for projections
- Video screen showing pictures of demolition and construction

OPTION 2





Elevation
1:100



Plan
1:100

- 3m tall, 15cm thick wall
- Two arches combined (two sectional views of dome)
- Arches intersecting provides structural support
- Video screen showing pictures of demolition and construction