INSTITUTE FOR ADVANCED ARCHITECTURE OF CATALONIA
MAA_ DIGITAL TECTONICS STUDIO 2010-11

SandstoneD

Thanks
Bardia Konshan_Marta Malé-Alemany_Victor Viña_Brian Peters
All Digital Tectonics Studio

A Grain Of Sand

If starry space no limit knows
And sun succeeds to sun,
There is no reason to suppose
Our earth the only one.
‹Mid countless constellations cast
A million worlds may be,
With each a God to bless or blast
And steer to destiny.

Just think! A million gods or so
To guide each vital stream,
With over all to boss the show
A Deity supreme.
Such magnitudes oppress my mind;
From cosmic space it swings;
So ultimately glad to find
Relief in little things.

For look! Within my hollow hand,
While round the earth careens,
I hold a single grain of sand
And wonder what it means.
Ah! If I had the eyes to see,
And brain to understand,
I think Life›s mystery might be
Solved in this grain of sand.

Robert William

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Studio Agenda_Abstract

Digital Tectonic Studio Agenda

In architecture, digital design and fabrication tools have given designers unprecedented means for executing formally challenging projects directly from the computer. Yet today, the impact of digital production in architecture goes far beyond the mere production of complex geometries.

The ongoing shift towards customisation of computational design methods through the development of scripts and algorithms is causing a fundamental shift in the architectural design process by enabling architects to surpass traditional Computer-Aided Design (CAD) tools. By liberating themselves from the creative and technical limitations imposed by software developers and managing their own digital design tools and interfaces with digital fabrication equipment, architects are indeed controlling the design and implementation of specific material solutions.

Just as pre-packaged CAD platforms are being updated or replaced by customised scripting tools, Computer-Aided Manufacturing (CAM) environments and computer-controlled (CNC) fabrication machines will surely undergo a similar shift and be supplanted by more open hardware solutions. Consequently, today's digital architects ought to formulate more critical positions on the status and characteristics of digital fabrication methods—which are currently being transferred from other disciplines—and begin to investigate the potential of producing highly specific and customised fabrication apparatuses for construction.

These new tools will unquestionably open up alternative building techniques and trigger innovative solutions for the production of architecture.

In this context, Digital Tectonics Studio outlines its agenda towards this new architecture expression. This road is guided by Marta Malé-Alemany, Victor Viña and Brian Peters.

Abstract
SandStoneD

Sand is the second most common element on earth next to oxygen and for centuries it was one of the most traditional base materials in architecture and craftwork. This base material is a naturally occurring granular material composed of finely divided rock and mineral particles.

Being granular, gives sand a unique physical behavior .It's a solid, but it reacts as a liquid. It takes shape easily, but in combination with other material it can be solid and rigid as stone.

This research explores the possibility to inject a fluid structural material into sand, using capillarity as the main parameter to emerge a potential new morphological system out of this ancient building material.

In fact the idea of injecting a fluid material to build underground structures, like docks or pilotis , is not new in architecture or engineering fields. But those practices basically are drilling a hole and fill it after.

Our intention is to explore injection ,using sand not only as a mold , but as a medium to generate forms that are being shaped by controlling the absorption of the binding material into the sand From a physical point of view, the specific fluid behavior of the injected material is directly related with the sand capacity to absorb it by capillarity (this phenomenon in physic is called as sorptivity) , with the pressure of injection , time duration of injection and also the angle between injection axis and gravity direction. Following this parametrical rules implied by material behavior and the aggregation process of fluid depositions like plaster, glue or cement the possibilities allows design multi-scalar applications and geometrical patterns.

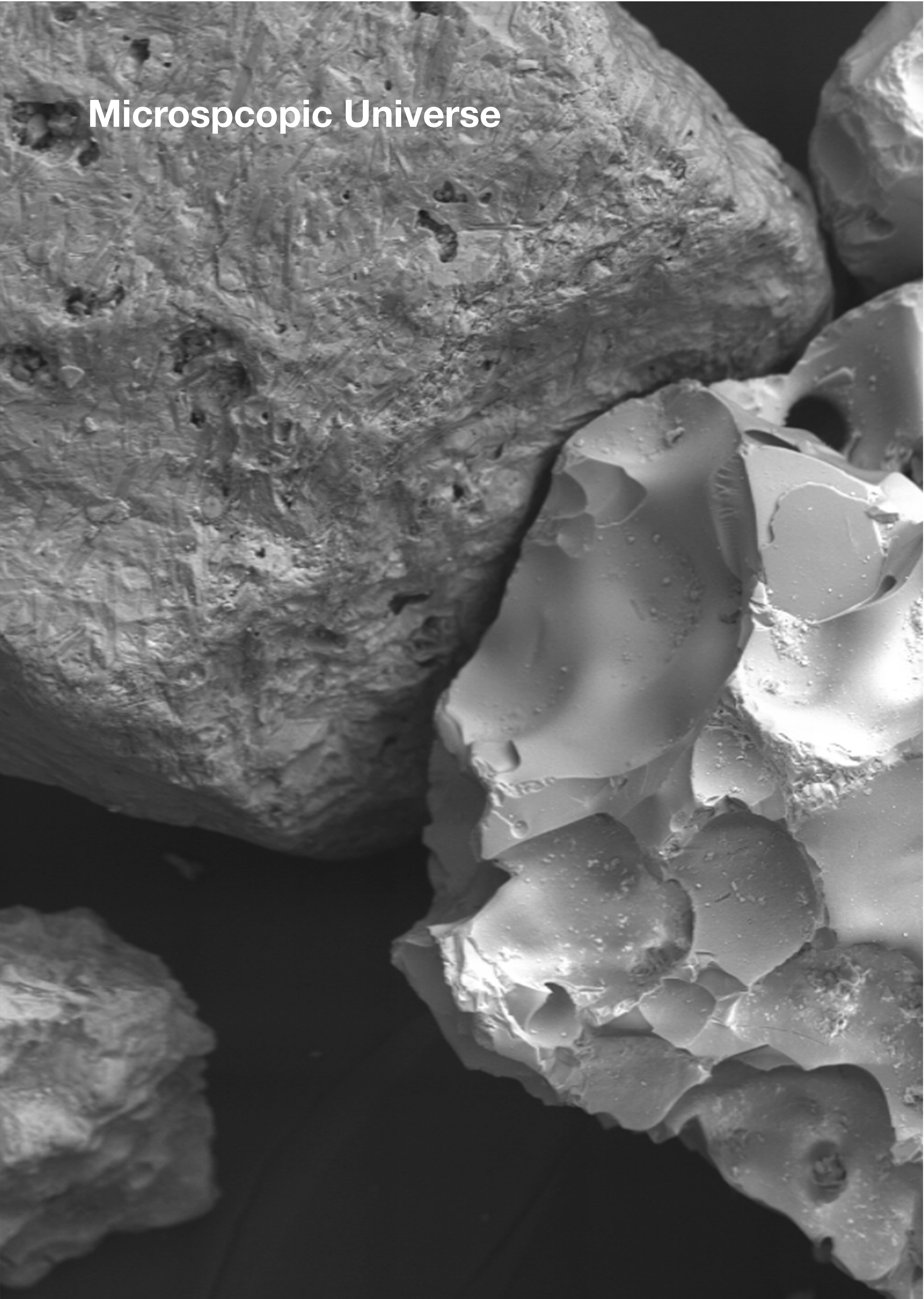
Our aim is to develop a digitally controlled construction system which allows "blind-design" process generating a continuous interaction between information and materiality to achieve an "emergent transformation" or digital materiality[1] .

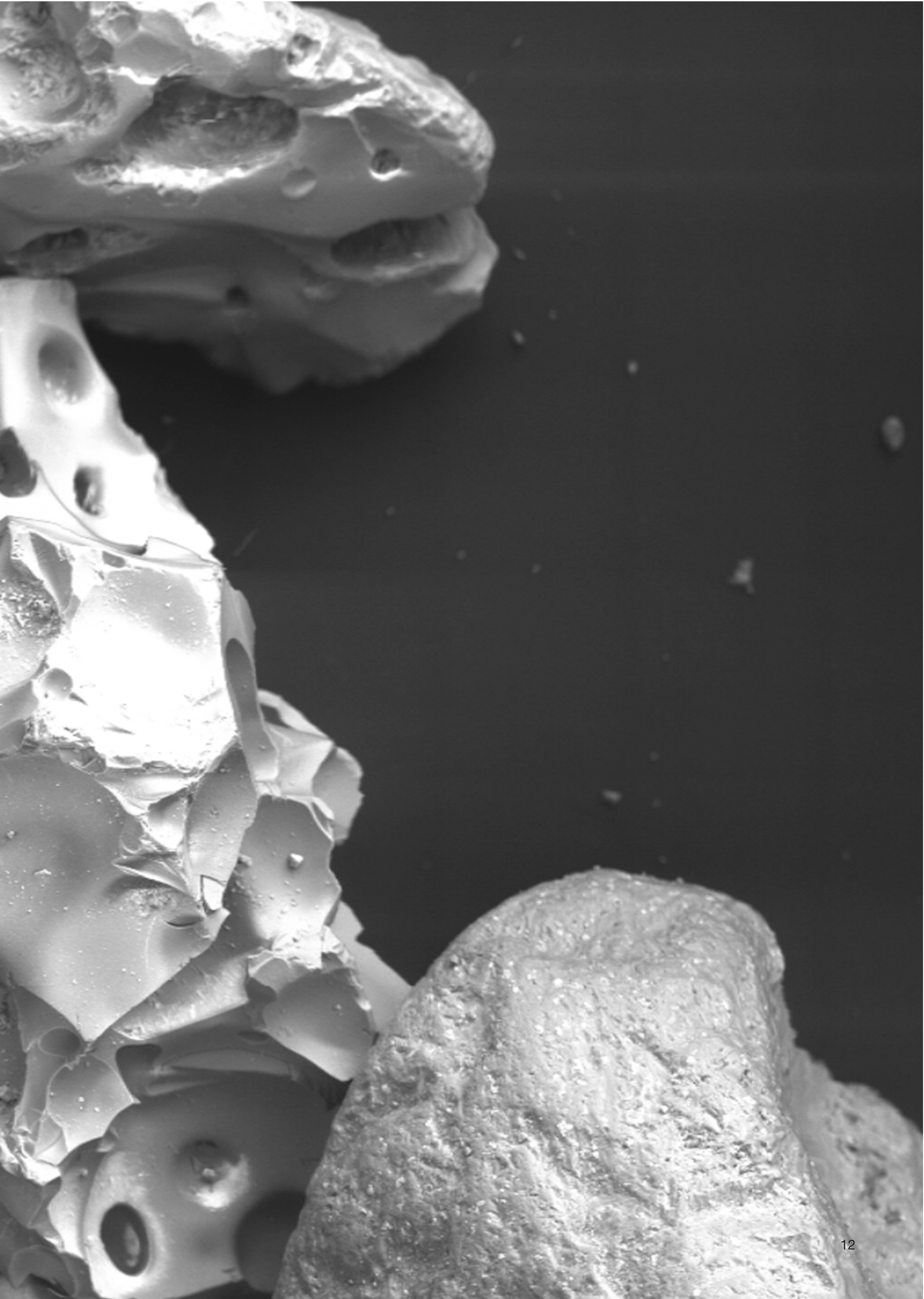
This process of fabrication could be deployed in areas where the presence of sand is generating a problem to control it (desertification) or to develop architectural components and furniture within a specific production line frame.

[1] Gramazio, Fabio & Kohler, Matthias, "Digital Materiality in Architecture", Lars Muller Publishers, Baden, Switzerland, 2008

Availability

Microspcopic Universe





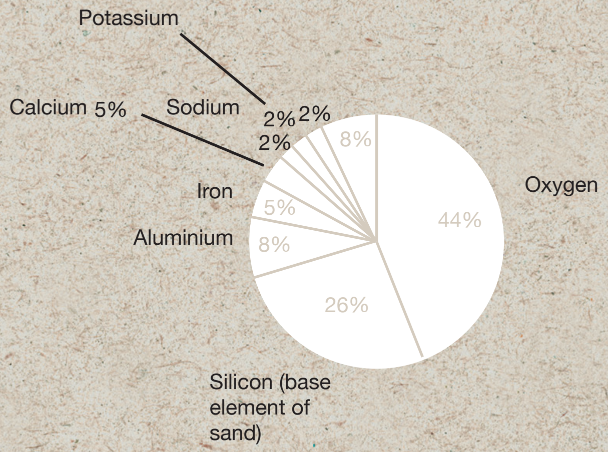
Introduction

Digital Materiality

Availability of sand

Sand is everywhere; in fact sand is the very symbol of ubiquity. Sand is the second most common element on earth next to oxygen and for centuries it was one of the most traditional base materials in architecture and craftwork. Oxygen and silicon are the most common elements in the ground. This is because many rocks are made mainly of a substance called silicon dioxide. This substance is a combination of silicon and oxygen[1] . Actually, some 41% of the Earth's land surface is classified as drylands[2] and a third of the earth is classified as a desert. Much of this surface is covered with arid (<25 cm/yr. rainfall) and semi arid land (25-50 cm/yr. rainfall). It is clear from the diagram below that the global distribution of arid and semi arid lands on the Earth are mostly of in the world is located within a belt along the equator, stretching from 30S to 30N in latitude[3] . Sand is everywhere; in fact sand is the very symbol of ubiquity[4].

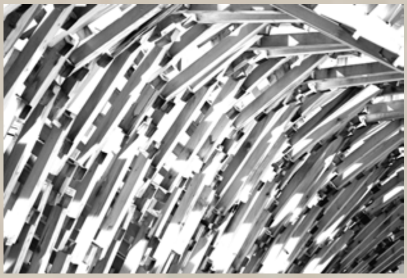
The availability of sand is impressive and its uses are while spread in different industrial fabrication process such as glass, bricks, concrete or even in agriculture as a base soil to cultivate specific natural products. It has been estimated that on the order of a billion sand grains are born around the world every second; add up these seconds over the billions of years of the Earth's history and the scale of change that erosion can cause is clear[5].



Is possible to find different types of sand all around the world, for instance, in a few places, black basalt lava breaks down into black sand, which is almost pure lithics. In even fewer places, green olivine is concentrated to form green sand beaches. The famous White Sands of New Mexico are made of gypsum, eroded from large deposits in the area. And the white sands of many tropical islands are calcite sand formed from coral fragments or from tiny skeletons of planktonic sea life. Sharp, clear sand grains are freshly broken and have not been carried far from their rock source. Rounded, frosted grains have been scrubbed long and gently, or perhaps recycled from older sandstones[6].

Even due this attributes and facts, there are some areas on earth where sand through water and wind erosion generates desertification problems reaching peaks that scientist called "tension zones". According to the USDA Natural Resources Conservation Service, there are about 7.1 million km2 of land under low risk of human-induced desertification, 8.6 million km2 at moderate risk, 15.6 million km2at high risk, and 11.9 million km2 under very high risk and about 1.413 billion people are involved in the last category[7]. What does it means that the availability of sand is related with social and economic issues then the situation and the real scenario is not only a problem but it an opportunity to use sand as a base material into a digital fabrication process.

Use of local materials for digital fabrication



Building materials typically considered as “local materials” are elements that are available locally.
Rapidly renewable plant materials like bamboo and straw, insulated concrete forms, dimension stone, recycled stone, recycled metal, and other products that are non-toxic, reusable, renewable, and/or recyclable are basically materials that is possible to use in local manufacturing process to the building site to minimize the energy embedded in their transportation[8].

There are multiples examples of digital fabrication using native materials showing impressive results in reducing energy or waste materials but in the final expression of the physical outcome. For instance, the architects Gramazio&Kohler are developing digital fabrication process using wood and clay bricks to achieve different geometrical patterns, and for the other hands, there are some artist working with traditional materials and applying digital information or control within the manufacturing process.

Native materials offer a substantial frame to work within the digital logic and new possibilities that allow to achieve a novel sustainable tectonic.

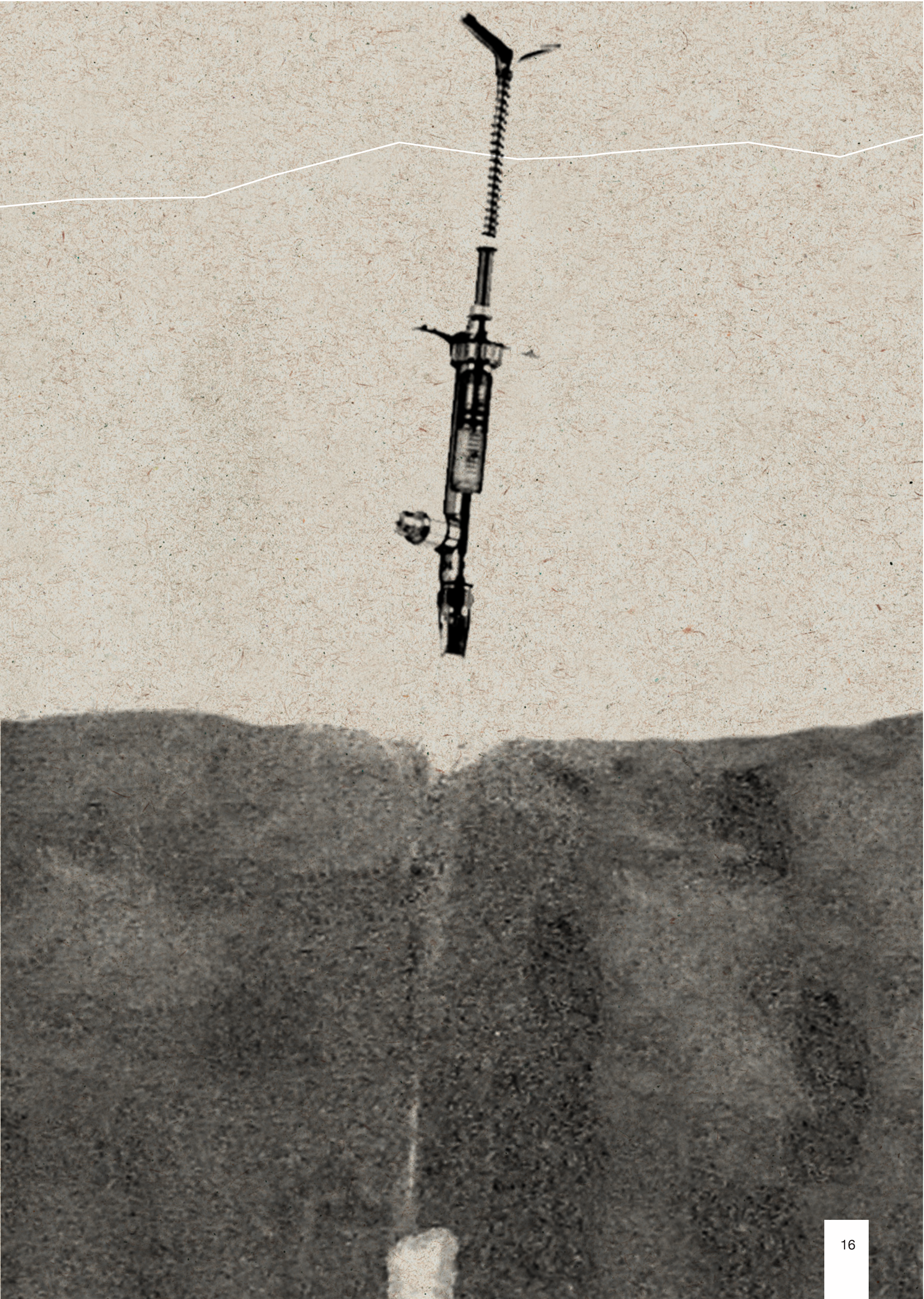
Sand injection technique

Within this specific frame of digital fabrication, we considerer to address an exploration based on the physical behavior of sand. Being granular, gives sand a unique physical behavior .It’s a solid, but it reacts as a liquid. It takes shape easily, but in combination with other material it can be solid and rigid as stone.

The idea is to explore the possibility to inject a fluid structural material into sand, using capillarity as the main parameter to emerge a potential new morphological system out of this ancient building material.

Our intention is to explore injection, using sand not only as a mold, but as a medium to generate forms that are being shaped by controlling the absorption of the binding material into the sand.

From a physical point of view, the specific fluid behavior of the injected material is directly related with the sand capacity to absorb it by capillarity (this phenomenon in physic is called as sorptivity), with the pressure of injection, time duration of injection and also the angle between injection axis and gravity direction.



Digital Materiality

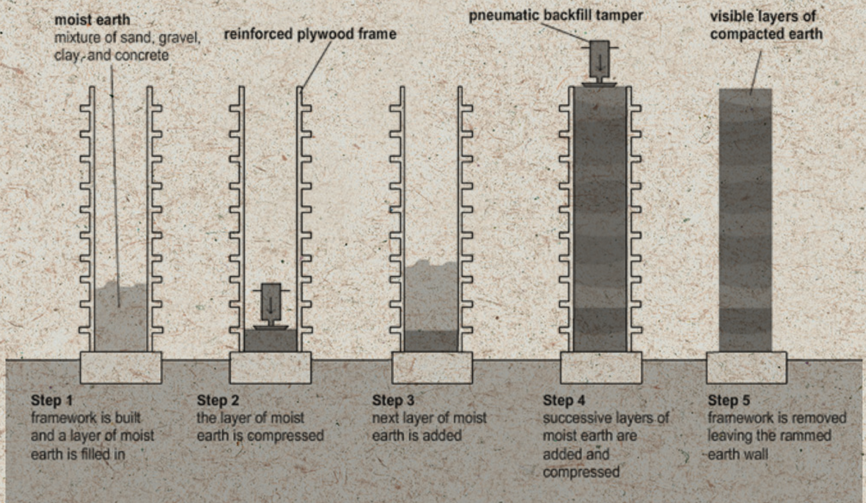
“Only nature is truly continuous. The buildings must contend with construction in parts. Operating thusly, under original sin, the will to continuity and discontinuity is the source of pleasure and pain, virtue and vice. Man is finite and so are his products[9]”

Reiser+Umemoto

Traditional techniques

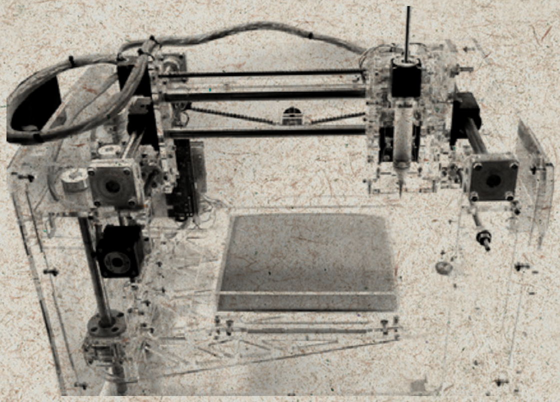
Nowadays, the term digital materiality is continuously present within different ongoing architectural investigation and researches. According to Gramazio&Kohler this concept describe an emergent transformation in the expression of architecture[10]. The consequences of this new scope between the material and the parameters to design relationship open a novel approach to think the architecture language and to achieve a manufacturing process where material becomes “informed”[11].

Traditional construction techniques use sand as a base material within a rigid and static cast frame to build different types and scales of structures and components. Most of these techniques used a handmade fabrication process and basically the manufacturing sequence provides information to the materiality just to control the vernacular result. The most common techniques are adobe, super-adobe, quincha, rammed earth or crafts techniques as pottery and ceramic. All these techniques are while spread around the world, basically for its low cost and the availability of the base materials besides its thermical and acoustic benefits.



Pottery and ceramic technique

Digital fabrication experiences



Digital fabrication experiences using sand as the main matter to work on it are related to use the main physical characteristic of the material like react as a fluid or a network between every single particle of sand or in the same field, its natural malleability capacity that allow to achieve multiples forms. A research laboratory called VergeLabs[12] is developing several explorations using sand to build Biomanufactured Bricks through different combinations of natural materials with sand.

Another interesting experience is a project of the SENSEable City Laboratory, a new research initiative at the MIT called "Continuous Tangible Interfaces: Bringing Clay and Sand into Digital Design", which explore the physical properties of continuous soft materials such as clay and sand, it is possible to bridge the division between physical and digital forms and potentially to revolutionise the current design process[13]. This project is not directly with digital fabrication but open a window to establish a relationship between real physical data and computation and analysis of them through an interactive platform.

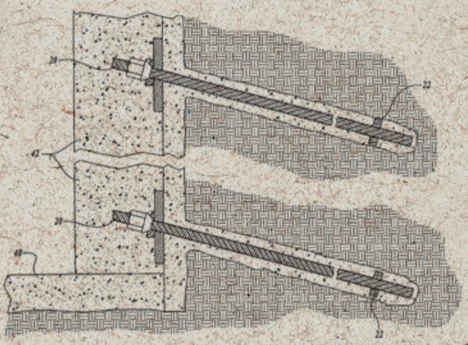
Sand offers a relevant range of operation to produce this idea that incorporates digital control through the manufacturing and construction sequence. The aim of this exploration is to develop a digitally controlled construction system which allows "blind-design" process generating a continuous interaction between information and materiality to achieve an "emergent transformation" or digital materiality[14] using sand as the base material to walk through this design process.

Examples of injection technique in construction

Experiences related with "injections" into the current construction scenario are directed to another sequence to put a structural fluid material into a sand or different soils. Basically, the processes to inject this fluid to build underground structures like docks or pilotis are drilling a hole and fill it after.

Ground Anchors technique is one of these techniques consisting of cables or rods connected to a bearing plate are often used for the stabilization of steep slopes or slopes consisting of softer soils, as well as the enhancement of embankment or foundation soil capacity, or to prevent excessive erosion and landslides[15].

Ground Anchors technique



In the same field, this technique is used to fix and repair concrete walls filling cracks, fissures or even structural situations through epoxy and toxic materials. At the same time, within the construction ambit, to inject concrete is rather well used but this technique is basically a system to pump concrete to a specific location mainly to upper floors or to cover from one point to another through a flexible and special hose.

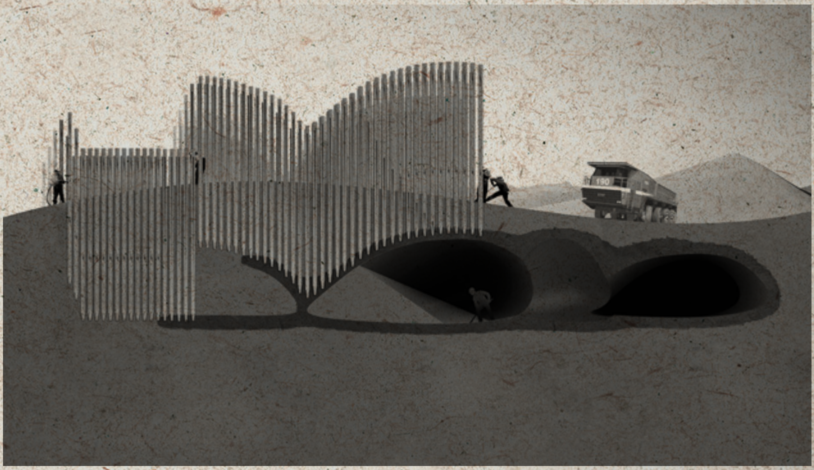
The strict means to inject is related with to put a liquid into another element, therefore to use this liquid and its physical properties into sand is something that the construction industry does not explore yet.

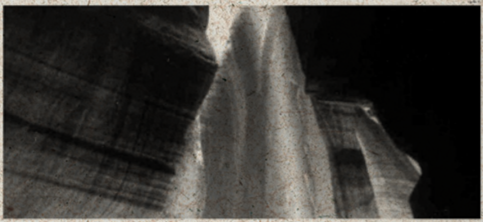
T.1 References

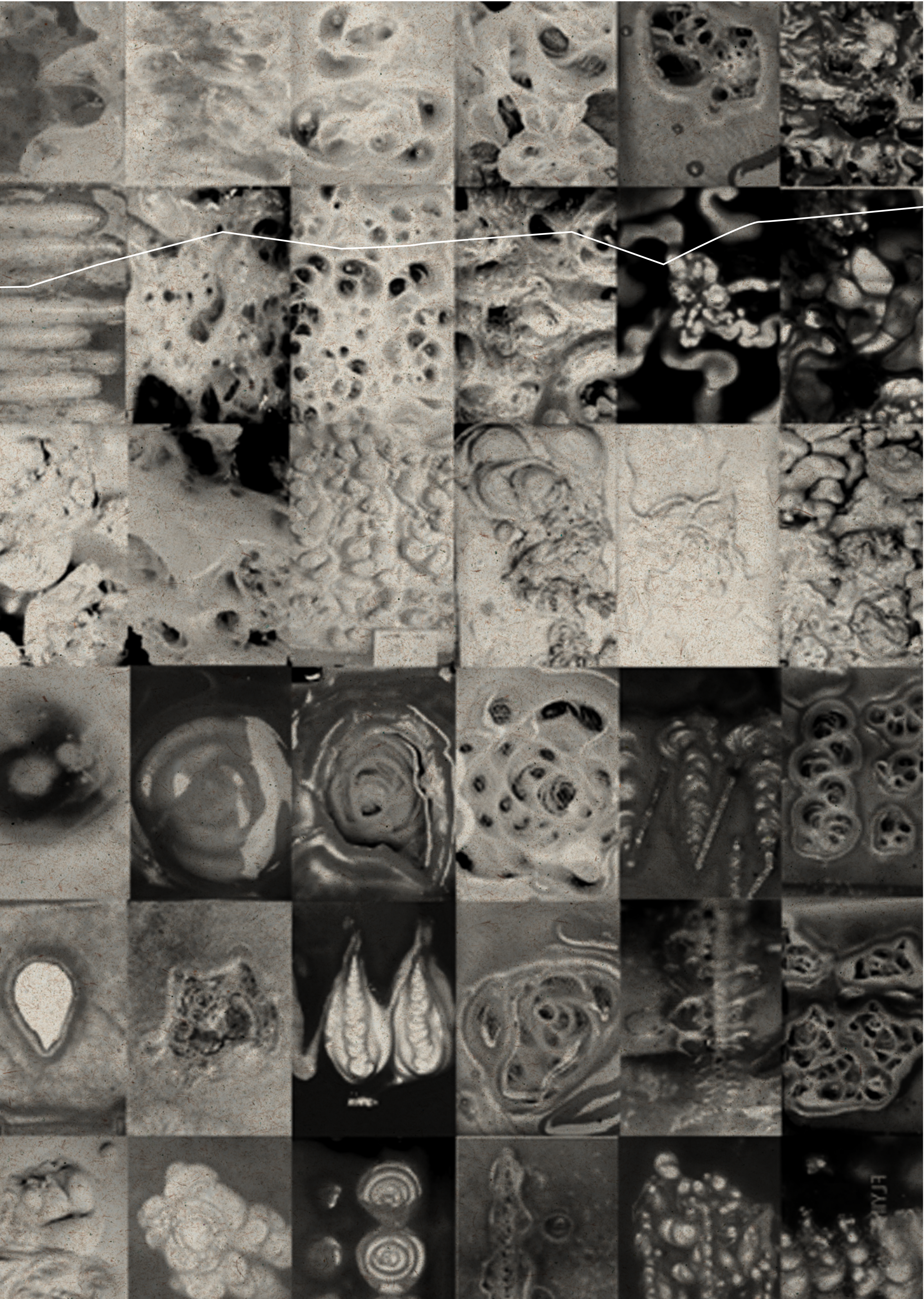
***DUNE, AA Thesis 07-08, Magnus Larsson*[16]**

Larsson project explores the biochemical process that happened into sand after "infect "it using a bacterium called bacillus pasteurii that solidifies loose sand into sandstones which are basically sedimentary rocks formation. The main idea of this proposal is to build a 6,000km-long wall of artificially solidified sandstone architecture that would span the Sahara Desert, east to west, offering a combination of refugee housing and a "green wall" against the future spread of the desert[17]. In other words, after inject and infect the sand, this wall could be controlled the desertification process.

Even due these qualifications, the proposal speculates and plays with the borders of the imagination, and does not provide too much information about the physical achievements and its consequences within a real scale frame. We consider this thesis as a fundamental support for our thesis, in order to use this experience as a platform to develop these lacks working on the base of







the digital tectonics of the main matter for this research: sand.

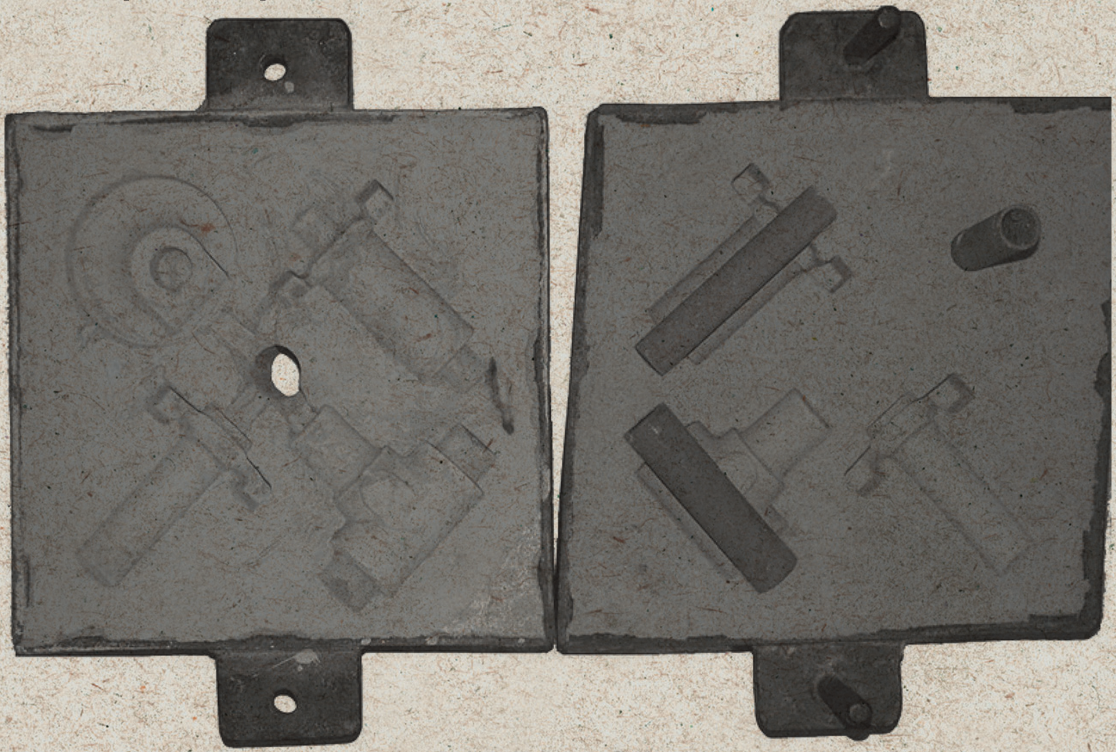
FLUID CAST, AADRL 09-10, Ena Lloret, Maria Eugenia Villafañe, Jaime de Miguel, Catalina Pollak

This project calls at stake traditional casting systems that work on the rigidity of a static to shape the material outcome. The most interesting thing about this exploration is the fact that work with fluid and uncontrollable base material such as water is not necessarily a constrain to generate or control an specific manufacturing process through computation. Fluid cast introduce a question to reconsider casting as a dynamic process of formation instead and use physical behavior of materials as a source to design.

In word of their authors: "(…) the study of material behavior within the logic of digital fabrication, our project explores a technology to set phase changing materials by using water as their catalyst. Our aim is to develop a digitally-controlled construction system, from which instant structures can be formed in water. Hence, the potential in thinking of the sea itself as a deployment environment opens up a wide range of possible applications"[18]

Sand Molded Cast Technique

This industrial manufacturing technique resulted in an interesting experience within our exploration; because engineers and industrial designers are using the malleability capacity of sand to mold a fluid to achieve through solidification process a specific form or shape. There are different types of sand molded process that are working basically over the same conceptual platform to vacuum a shape into sand to pour a final fluid material to achieve a final outcome.



Full Size 3D layering Printing System

In 2004 Enrico Dini patented a Full Size 3D layering Printing System based on use pf Epexy Resin and in 2007 patented an improved method based on use of ecologic inorganic binders. Monolite UK Ltd was set up by Enrico in 2007 with the aim of producing and selling 3D Printers of Buildings together with related materials, products and services, directly or through associates.

After four years research and development Enrico Dini has recently tested the 6mx6m prototype successfully. This new machin-

ery enables full-size sandstone buildings to be made without human intervention using a stereolithography 3-D printing process that requires only sand and our special inorganic binder to operate.

Stereolithography, also known as 3-D layering or 3D printing, allows the creation of three-dimensional (3-D) objects from CAD drawings.

It is already used to manufacture small objects.

To achieve a building on a full scale will only require a machine of adequate size and the right binder. Enrico Dini has opened the way for application of this process on a large scale.

The Monolite building process is similar to the “printing” process because the system operates by straining a binder on a sand layer (more on materials in the next section). This is similar to what an ink jet printer does on a sheet of paper.

Foot notes

1 Common Elements - Earth Elements, Water Elements, Air Elements, Elements of Life, Elements in Space - Oxygen, Hydrogen, Iron, Found, Silicon, and Stars http://science.jrank.org/kids/pages/212/Common-Elements.html#ixzz1MiX3wATY

2 Migration and desertification, UNCCD the maticfact sheet series N o . 3, United Nations Convention to combat desertification

3 Indiana University, http://www.indiana.edu/~geol116/Week11/wk11.htm

4 Alden, Andrew. "About Sand", http://geology.about.com/od/sediment_soil/a/aboutsand.htm

5 Welland, Michael, "Sand: The Never-Ending Story", Director's Circle Books, 2010

6 Alden, Andrew. "About Sand", http://geology.about.com/od/sediment_soil/a/aboutsand.htm

7 Hari Eswaran, Paul Reich, and Fred Beinroth, "Global Desertification Tension Zones", Proc. Of International Soil Conservation Organization Conference, Purdue Uni ver sity, IN. 1998

8 http://en.wikipedia.org/wiki/Green_building

9 Reiser, Jesse and Umemoto, Nanako, "Atlas of Novel Tectonics", Princeton Architectural Press, 2006.

10 Gramazio, Fabio & Kohler, Matthias, "Digital Materiality in Architecture", Lars Muller Publishers, Baden, Switzerland, 2008

11 Ibid

12 VergeLabs is an architecture and design practice with a focus on developing performative research topics in architecture. Founded in 2006 as a partnership between Ginger Krieg Dosier and Michael Dosier, VergeLabs research topics include the areas of material science, ecological impact, architectural performance, computation and fabrication.

13 H Ishii, C Ratti, B Piper, Y Wang, A Biderman and E Ben-Joseph, "Continuous Tangible Interfaces: Bringing Clay and Sand into Digital Design", BT Technology Journal, Vol 22 No 4, October 2004.

14 Gramazio, Fabio & Kohler, Matthias, "Digital Materiality in Architecture", Lars Muller Publishers, Baden, Switzerland, 2008

15 World Technology Evaluation Center (WTEC), Division of Loyola University Maryland.

16 Holcim Awards 2008 Africa Middle East, "Next Generation" 1st prize: Dune anti-desertification architecture, Sokoto, Nigeria, http://www.holcimfoundation.org

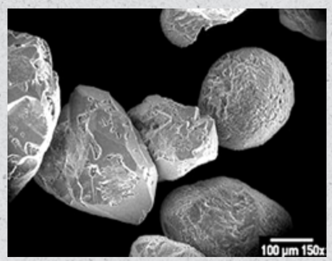
17 http://www.holcimfoundation.org

18 (FAB)BOTS Customized robotic devices for design and fabrication, Disseny Hub Barcelona (DHUB), 09- 2010, www.dhub-bcn.cat

Material System / Behaviour

“The birth of a sand grain is a microcosmic event, a flap of a butterfly’s wings heralding greater change and a larger creation. Each grain carries the equivalent of the DNA of its parents and develops a character through its life that is molded partly by its parentage, partly by its environment. Compared to the scale of a human life, however, the sand grain’s story is never-ending, and rebirth is a regular event”.

Michael Welland



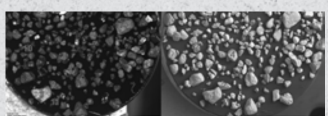
M.0 Understanding Sand Behavior

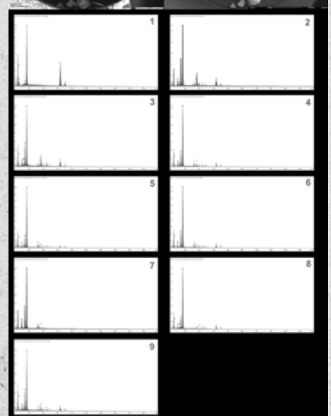
Physical behavior

Definition

Sand is a granular substance composed of finely divided rock and mineral particles that behave and react as a fluid with unpredictable events in its internal structure.

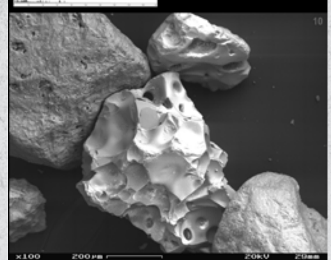
Geologist defines sand particles have a range in diameter from 0.0625mm (or 1/16 mm, or 62.5 μm) to 2 mm. The composition of sand is highly variable but mostly is silica (silicon dioxide, or SiO_2), usually in the form of quartz, which, because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering[1]. But by far the majorities of sand grains are made of one of the Earth’s most common ingredients, the mineral quartz, and are formed by the process that works, day in, day out, on every exposed piece of land on the Earth’s surface—weathering[2].

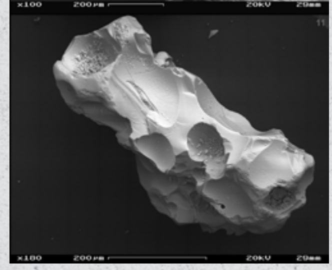




Internal structure/chain behave

According to Michael Welland, sand has an internal structure pilled high from microscopic chains and networks and through that way they carry most of the pressure from the weight of the material above them[3]. Its behavior is directly related with its size and the composition at the end is irrelevant:”The behaviors of anything made up of relatively hard bits and pieces of a particular size, regardless of what the bits and pieces are made of, are unique and, in the case of sand, quite odd”[4]





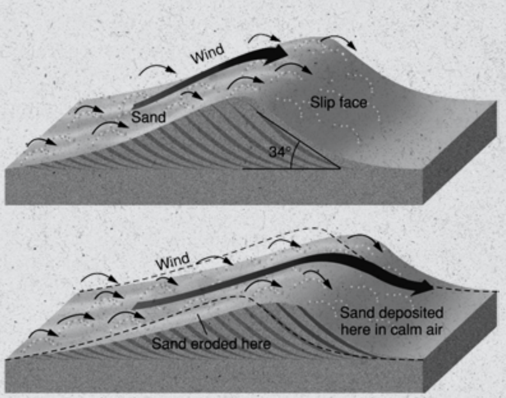
Its behavior is unpredictable and mysterious; it can be assume a big amount of weight and fly and transformed its shapes by wind and water. Sand’s essence is to being a granular fluid, to being a huge example of how network can work when every single participant is an active part of the whole. That is the beauty of sand, allows us not only to understand natural and physical behaviors, but open a metaphysic window to observe our nature and our environment. As Welland says, every sand grain in the world is unique, an individual.

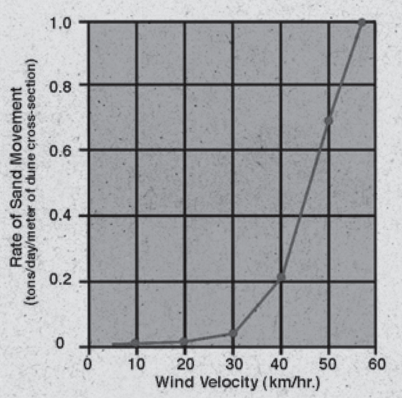
This “chain behave” allow us to explore the use of sand as a medium to conecte grains of sand and solidify or frozen the sepecific instant of this endless chain. To work using sand as a medium, our frame is in between sand particles, among them, use these millions of empty spaces to conecte the tiny rocks to achieve a final solidification outcome.

We want to frezze an instant of these multiples and microcosmic events.

Movement/ wind

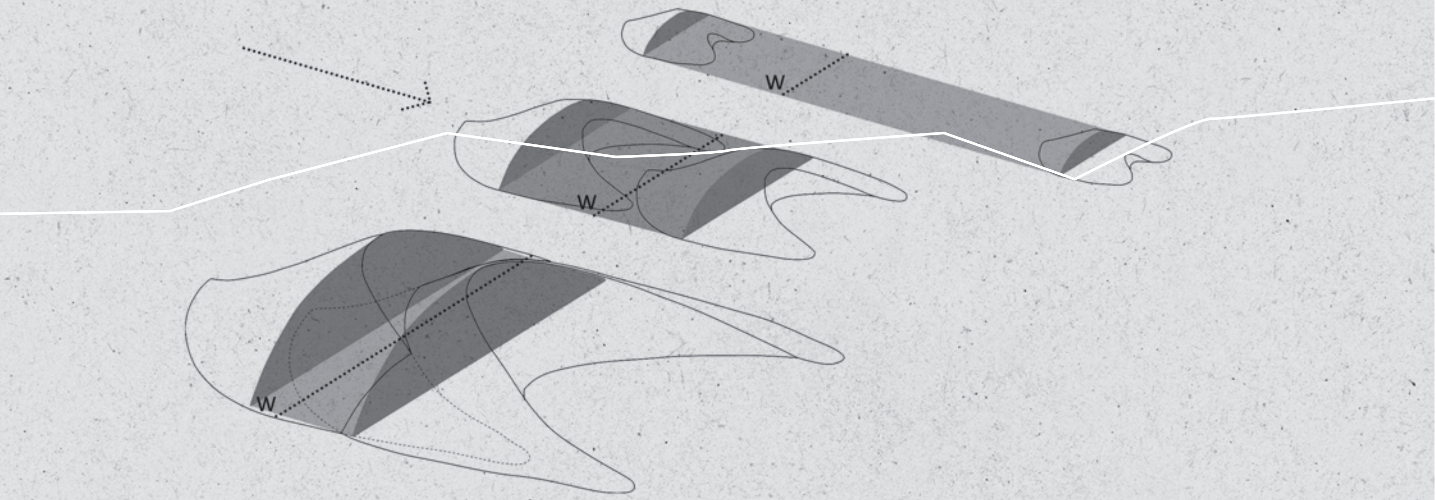
One of the ways that nature allows sand to travel on Earth’s surface is through wind. Air tends to flow from areas of high pressure to areas of lower pressure and the patterns of behavior of wind on Earth are related with the Equator. Heating is so intense because the angle of inclination of the sun at the equator is 90o and because of this density difference the air must rise in order to achieve a more stable, equilibrium state. As the air rises, it moves to the north and south, as shown above. After it has become equilibrated at higher elevation it begins to cool and becomes denser than the air around it, in part because of the water vapor it contains[5]. The directions and intensity of wind is fundamental to understand the movement of the sand through arid lands and at the same time the behavior of dunes and surfaces where sand govern the landscape.





As we mentioned in the introduction, there are places that the moving forward of sand generate some problems “invading” urban and agricultural places.

Wind shapes the type of dune; sculpt their surfaces and volumes through a continuous and delicate polish. Layer by layer, sand advanced creating patterns of formations over the landscape. Individual saltating granules form transversely (perpendicular) to the wind’s direction forming small ripples. As more granules collect, dunes form. Sand dunes can form in any landscape on



Relation between the dune velocity and its height. On this sketch are three dunes at initial time and after some time t. It is obviously, that smaller dunes are faster and that the area W (width) is almost independent of the dune size.

barchans	height	propagating speed
small	3m	15-60m/year
large	15m	4-15m/year

Earth, not just deserts[6]. The main parts of dunes are the windward (stoss) slope, crest, slipface and leeward slope. The stoss side of the dune is transverse to the predominant wind direction. Saltating sand granules travel up the leeward slope, slowing as they accumulate other granules. The slipface forms right underneath the crest (the peak of the sand dune), where granules reach their maximum height and begin to slope steeply down the leeward side[7].

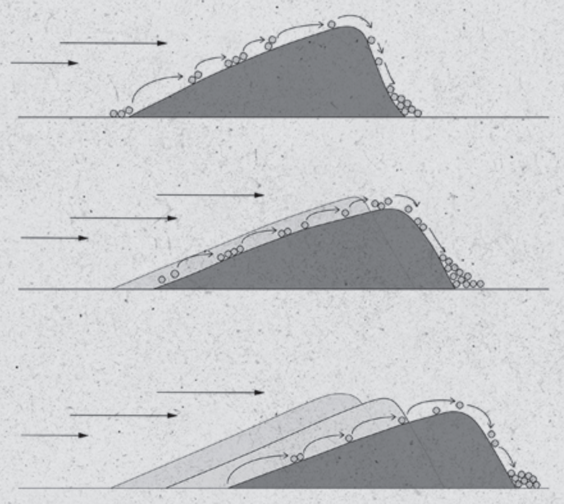
Barchan is the most common sand dune formation around the world, and is composed basically by long the same direction as the predominant winds and have a single slipface. There another formation like linear, reversing or stars dunes formations and all of them are natural reactions by the direction or directions of the wind.

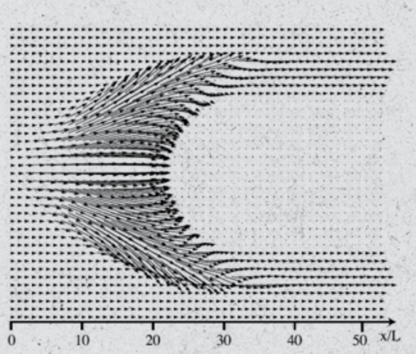
The transport power of wind is deceptive. Although it takes nearly 20 km/hr wind velocity to move significant amounts of sediment, the carrying power of wind rises exponentially as the wind velocity continues to increase[8].

Sand dunes cover only about 20% of the desert and essentially sand is provided internally, by the wind reworking ancient river and lake beds and by the sandblasting of the exposed rock, mechanical weathering, and erosion. According to Welland, to start a sand grain moving, the wind speed must be considerably greater than that of a current of water . Every grain of sand has an endless journey through deserts, shaping landscapes and moving forward over human places.

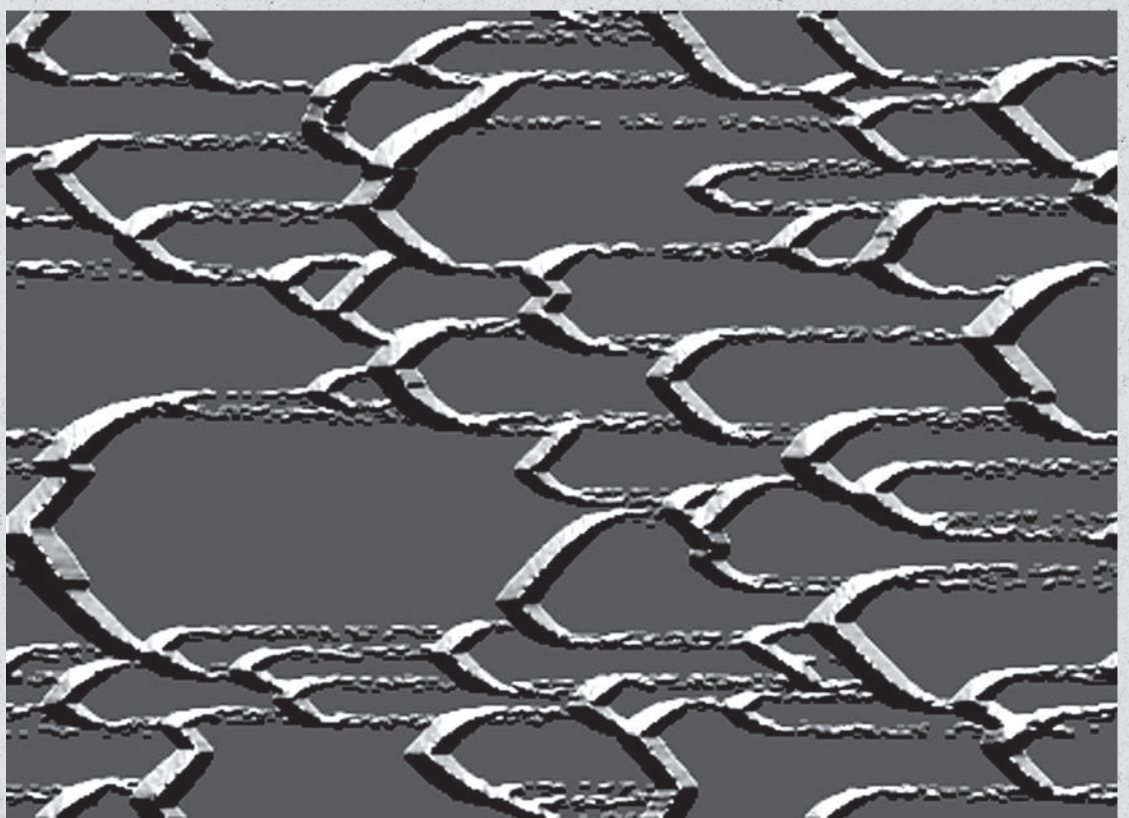
Physical behavior of natural formation of dunes is related with the action and speed of wind. Welland gives more details about it "there is a velocity gradient, whereby the wind speed increases with the height.Velocity gradients cause pressure gradients, and pressure gradients mean planes –and grains- can fly. What happens on a very small scale very close to the surface of the ground in the desert is critical to the grand-scale results." [10] To move a particle of sand depends basically of two things: the size of the grain and the speed of the wind, for instance, the minimum wind speed necessary to move the fine sands of the desert is around 16 Km per hour. Grains travelers create a parabolic curve into the air generating collisions over the sand surface building an extremely complex system of relationships and reactions.

This process is relevant in order to understand the environment and its variables implies in our exploration.





The arrows indicate the direction of the total sand flux on the whole barchan. The deviation towards the horns is clearly visible as the sand captured by the slipface.



M.1 Research Field

Desert Rose

Solidification

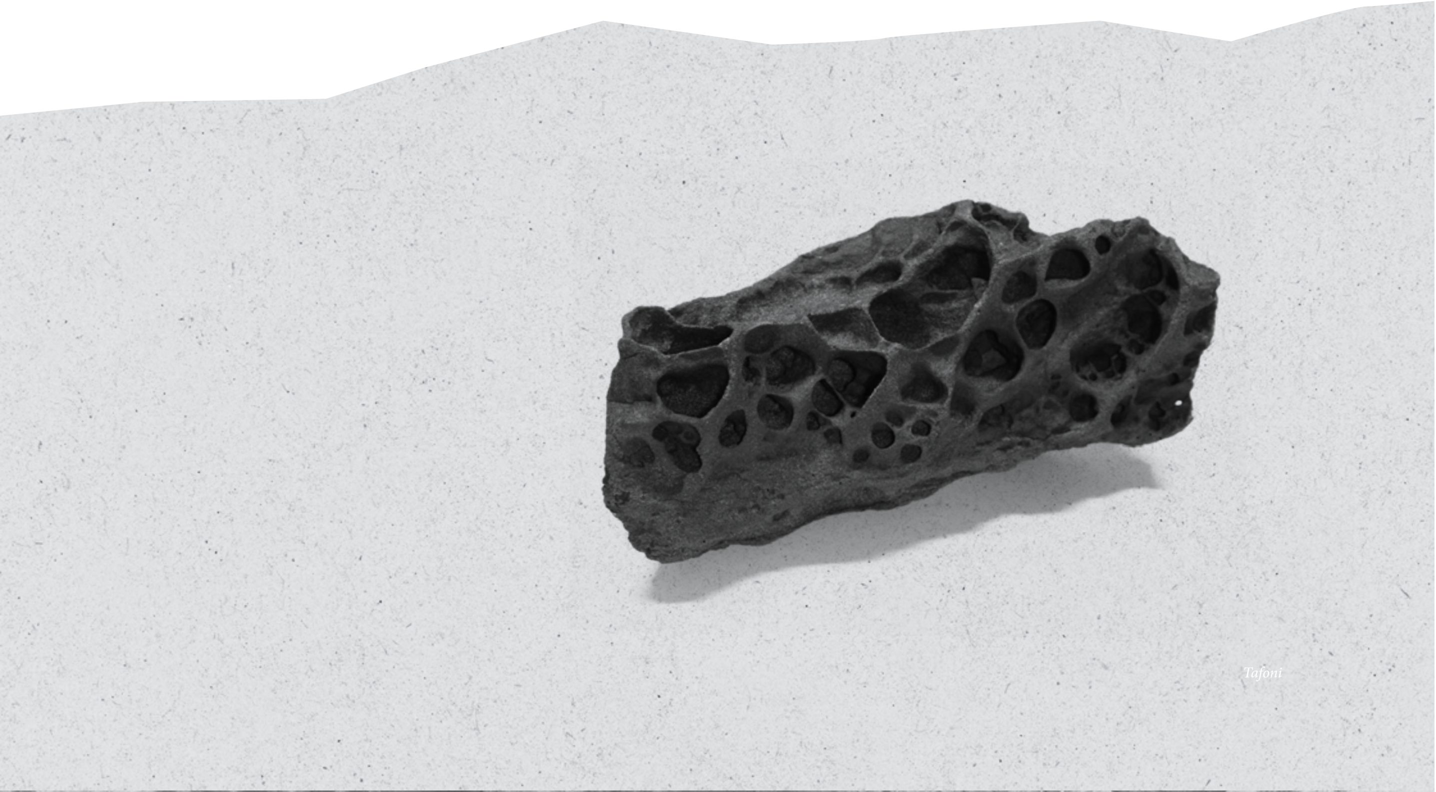
There are several examples of solidification of sand. Usually called "sandstones", these natural processes are very linked with the composition and specific environment of the sand. Normally, when particles of sand are mixed with substances as gypsum or clay (substances able to link them), a millinery sequence of layering through evaporation start solidify grain by grain to achieve a final outcome called sandstone.

Sandstone has two different kinds of material in it besides the sediment particles: matrix and cement. Matrix is the fine-grained stuff (silt and clay size) that was in the sediment along with the sand whereas cement is the mineral matter, introduced later, that binds the sediment into rock.[11]

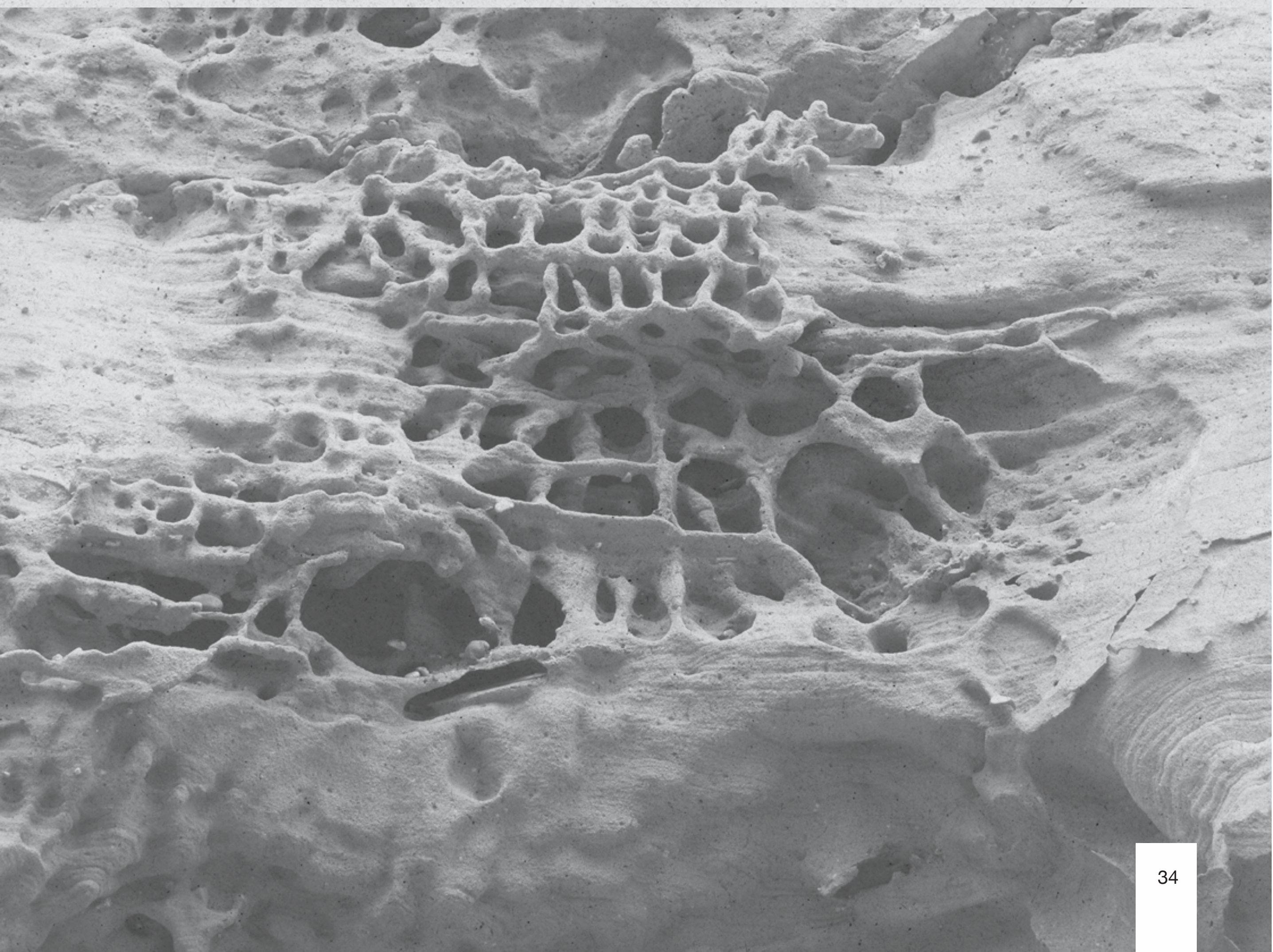
For instance, one of the most famous and interesting examples is the tafoni sandstone, which from the geological point of view is unique class of cavernous weathering structures made by differential and salt weathering processes.[12]

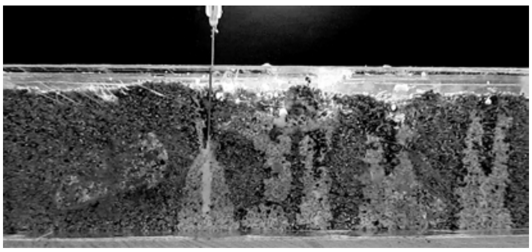
Tafoni-like features comprise a class of relatively deep, rounded to elongated natural rock cavities bored primarily by rock weathering processes and secondarily by erosional processes. When the water dries, the minerals form crystals that force small particles to flake off the rock.[13]

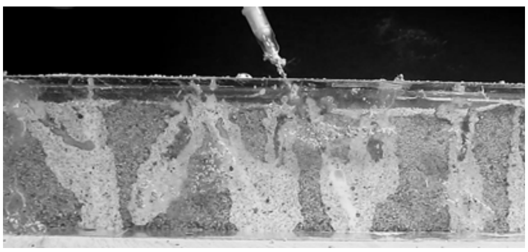
Another example of solidification base on sand is known as "desert rose", which basically is a natural formation made of minerals gypsum and barite with poikilotopic sand inclusions. The final outcome is a fantastic vernacular expression of these types of sandstone formations. Different slides growing in multiples angles and positions are emerging through this process given a complex expression.

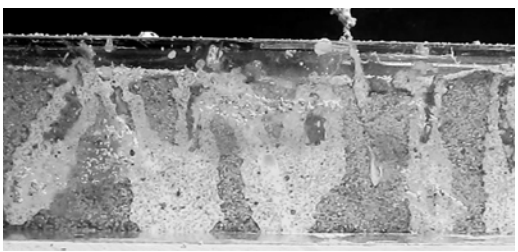


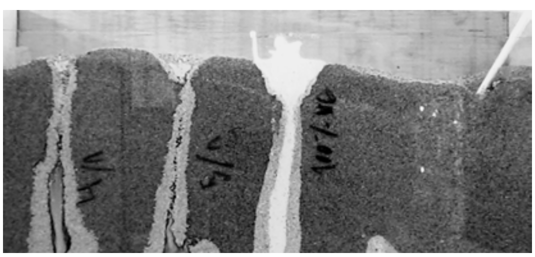
Tafoni











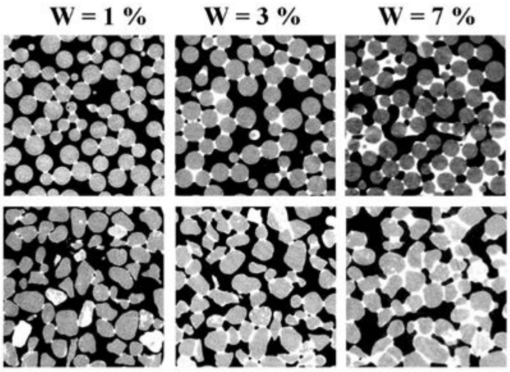
Technique/injection_aggregation

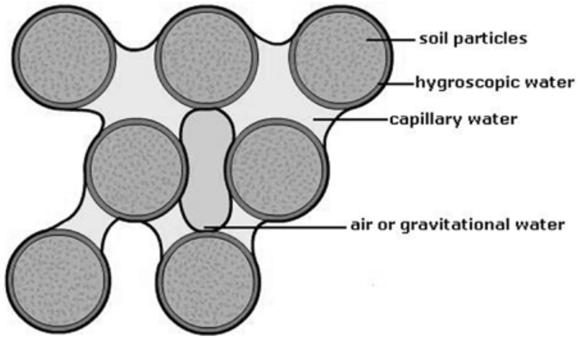
As we mentioned at the introduction our intention is to explore injection, using sand not only as a mold, but as a medium to generate forms that are being shaped by controlling the absorption of the binding material into the sand. The natural behavior of sand it is related always with movement, transformation and an endless network this very unpredictable group of individuals. Welland provides a clear explanation to illustrate this “society” of particles working together:.

“The weight and pressure distribution within a pile of any granular material is determined by the way in which the individual grains contact each other and distribute the stress. Quite commonly, grain shapes and sizes mean that there are microscopic chains and networks of grains that are oriented and in contact with each other in such a way that carry most of the pressure from the weight of the material above them. These chains seem to behave like the soaring arches of Gothic cathedrals, which serve to transmit the weight of the roof, perhaps a great dome, outward to the walls, which bear the load.” [14]

According to this, we could infer that pressure into underground materials and specifically sand, is not linear and it depends on its particular and specific relationship between sand particles. Pressure into sand respond to a level of complexity related with the range of communication and interaction which create a high complexity information system of transference. This specificity is basically important because this exploration is playing in between of the particles, in its gaps, among them, finding a way to freeze these multiples relationship using a fluid

which travels among this microcosm.





The act to inject a liquid into sand needs to understand this natural and unpredictable behavior of sand basically on two different fields: the physical act to inject a rigid element to reach an underground point of injection and therefore, the physical reaction of this fluid after the injection.

The first field has a fundamental question; ¿how a physical element can reach an underground point into sand avoiding the natural and irregular pressure of sand? Doing different approaching through test, we release that the diameter of the nozzle to inject the fluid is not relevant. The reason is clear: we just need to transport a fluid material to a specific location in order to spread out it, therefore the fluid just need time or pumping pressure to start working among sand particles, as a consequence we can work with a very thin nozzle to avoid the pressure of sand and bring the fluid material underground. At the same time, a thin nozzle allows us to control the amount of material injected and be more accurate in decision related with design.

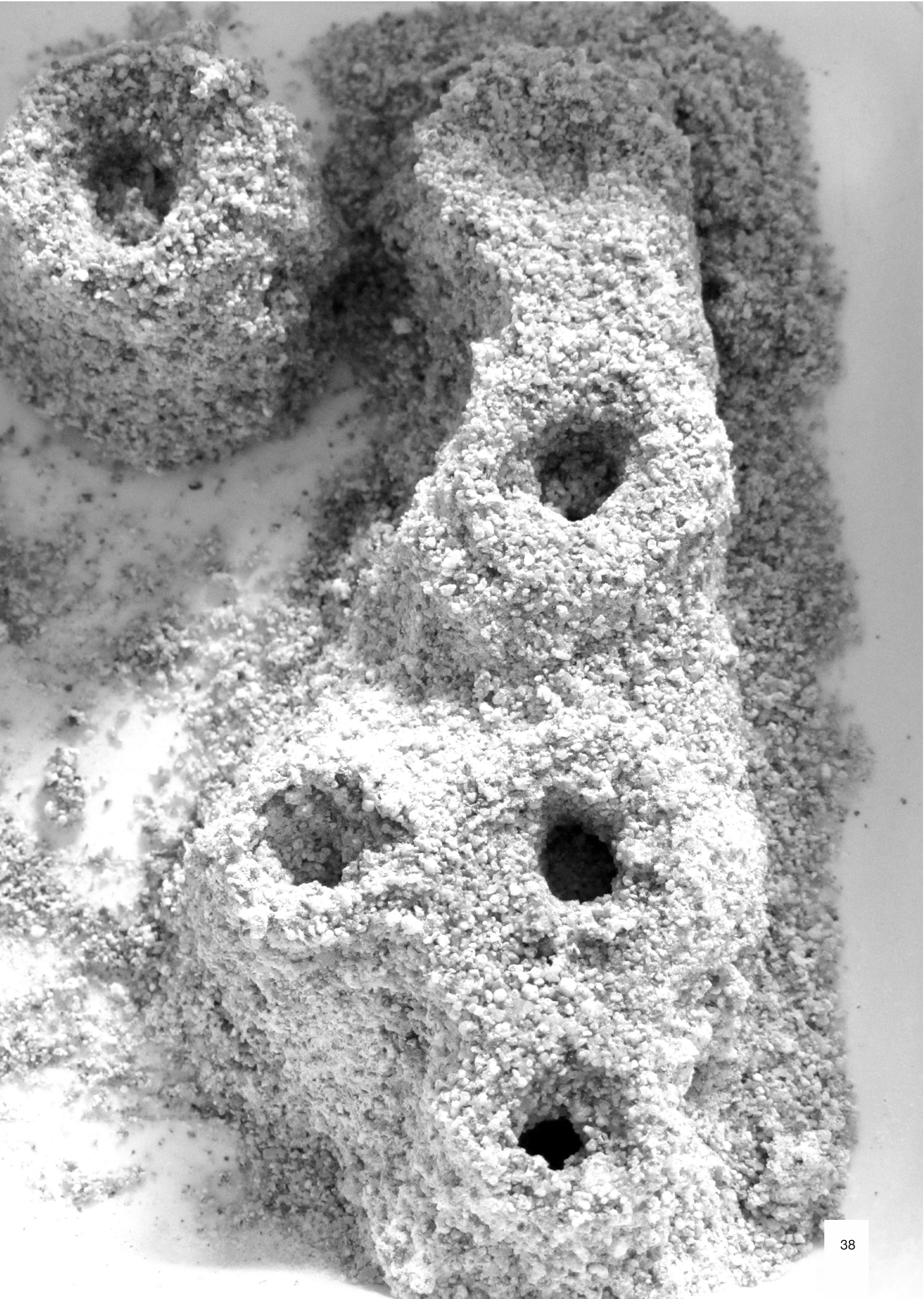
To the other hand, if we are able to avoid the physical impediment that sand pressure generate, ¿what kind of reaction we are going to have to control or to understand? A fluid reacts by absorption into sand spreading out trying to find a gap to go beyond. This physical reaction is unpredictable and it depends on a bunch of physical variables such as infiltration, capillarity, sorptivity, gravitational behaviors, etc. Some of them are possible to controlled, but majority allows is just to manipulate the application not the reaction. This unpredictable scenario is the field of this research and through the process to understand this, is possible to achieve an emergent technique and therefore an emergent expression and tectonic.

Hydraulic conductivity / infiltration_sorptivity_capillarity

As we explain before, the physical behavior of a fluid into sand has many variables within hydraulic conductivity and is infiltration the main concept to understand our field to research.

An Australian physicist called John R. Philip studied this field and his work on the theory of infiltration was well recognized for the scientist community. He derived the theory for one dimensional infiltration and developed equations which described the infiltration on both a short term and long term scale, with the revelation that when ponded infiltration in uniform soils occurs, the flow will approach the saturated hydraulic conductivity:

$$I = S\sqrt{t} + At$$



where S is sorptivity and A is the steady-state infiltration rate.[15]

Basically, infiltration is a process where fluid comes into contact with soil and behaves a vertical movement in a soil. Within this process, sorptivity express or interprets the behavior of the fluid among particles being defined as the capacity of a material to absorb or desorbs a fluid through capillarity. There are three forms of behavior of a fluid into soil: capillary, hydroscopic and gravitational.

Capillarity action is defined as the tendency or ability of a liquid to flow against gravity where liquid spontaneously rises in a narrow space, as the spaces that we find into granular materials. Also, hydroscopic reaction is basically a very tiny amount of absorption of the particles over its surfaces, and finally, gravitational reaction is pulled out of large pores by gravity after rain or irrigation.[16]

Mechanical properties of wet granular materials are due to random network of capillary bridges which form between adjacent grains, exerting attractive forces by surface tension of the liquid.[17] In the wet granular media with small liquid content, the liquid forms a bridge at each contact point, which induces a two-body cohesive force due to the surface tension. [18]

This process of absorption establish our parameters to understand what type of solidification we can achieve doing this injections and how we can start playing with capillarity and the gravitational water that generate diverse patterns and relations between the liquid and the solids. Our project is about a continuous relationship between solids, fluids and empty spaces no matter what scale of work would be.

M.2 Material Components

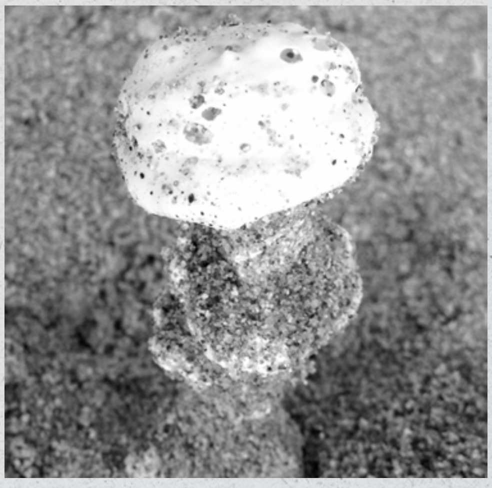
Fluid Structural Material_viscosity+sorptivity

To solidify sand until now, we know that an external element at least has to be part of the equation. In order to use injection as a technique, we need a fluid able to react into sand environment and to generate a relationship between each grain. The main condition of this liquid is the viscosity in its internal structure, in order to achieve the main goal of the exploration.

In theory, viscosity is a quantity expressing the magnitude of internal friction in a fluid, as measured by the force per unit area resisting uniform flow. Flow is critical to understand the concept related with the interaction between fluid+solid demanded for this research. ¨

First experiences of tests using different materials as plaster, Portland cement, white glue, or even clay showed interest result in this field; when we were using a high level of viscosity, the reaction of the fluid into sand generate a very low amount of absorption by capillarity, then at the end the final outcome just use sand as a cast instead of a medium, therefore the fabrication of the test needed a big amount of energy to pump the fluid underground and at the same time the geometrical pattern were limited just to fabricated "mushrooms". In other words, if we inject a fluid with a high viscosity, we are just going to make a hole putting pressure in all the directions surrounded into sand. Although, these types of depositions are able to connected over the surface and create some geometrical systems, but constrains and the demand of energy shown an improper scenario to work on it.

Although some of these geometrical combinations could be interesting and related with structural real experiences like Johnson Wax Building by Frank Lloyd Wright, the final outcome is not related with the real potentiality of this research.



When we started working with a low viscosity fluid, we realized that through the flow of the fluid using sand particles as a platform to "swim" into them, the reaction was a sort of basic genome infecting and spreading its torrent into this particular medium. Solid, fluid and empty spaces started working together establish an order base on a physical phenomenon. These physical parameters allow us to address our ability to recognize naturally grown organizational forms and to interpret their internal order. [19]

Experiments whit low values of viscosity allow us to achieve emergent patterns and combinations just through a few injections with different setting of distances between each one. The results were interesting from the beginning. They showed that using capillarity as a source of generate geometrical systems the possibilities grown exponentially. Sand started working as a medium to generate interaction between the all the parts included into the equation: **solid+fluid+empty**.

Through this interaction emerge an expression of the physical phenomena within the application of this fluid. After this, experiments started to take different levels of interaction and information achieving more complex systems. The distance of each point of injection, the amount of material injected, time and deep of the injections are now the parameters to control and inform the digital fabrication process within this technique and start using tools to shape and inform materials to react doing specific design operations.

Foot notes

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MACHINE System/behavior

M.0 From fabrication/material processes into design (bottom-up)

Another approach to 3D printing

Controversial 3D printing methods

Capable of making a part from scratch in just hours, 3D printing is used to create models to determine if a design meets the customer's concept and expectations. It is also used to create prototypes of parts to test their form, fit and function with other parts in an assembly.

Using 3D printing technologies such as laser sintering and electron beam melting, "rapid prototyping" evolved into "rapid manufacturing," in which short runs of actual finished parts are made. Such techniques are also used to create products customized for each person, such as hearing aids, dental crowns and medical implants.

3D printing is also used to make tooling, such as molds and dies, as well as patterns for castings. Either the actual mold or the model to make the mold can be produced more quickly and less costly than with conventional methods.

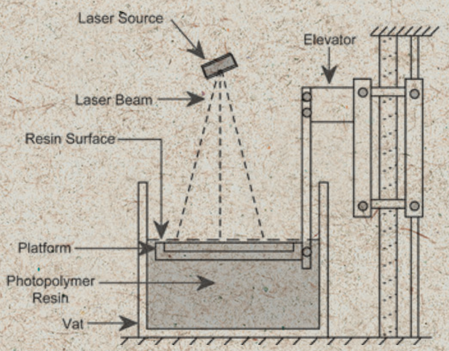
Although various techniques are used, all 3D printers use methods of "additive fabrication," methods, building the part one layer at a time, with layers ranging from a millimeter to less than 1/1,000th of an inch. The building material can be a liquid, powder or sheet material that is cured by heat, UV light, a chemical reaction or other method.

The term "3D printing" has evolved to include both rapid prototyping and rapid manufacturing. Initially, 3D printers referred only to the relatively small, inexpensive office-based machines that jet a wax, photopolymer or binder. Increasingly, the term refers to any machine that uses a method of additive fabrication either in the office or shop floor.

There are numerous 3D printing methods, including the cutting of paper, plastic and metal sheets with a laser or knife, and the layers may be glued or fused together. The more common methods use filaments, liquids or powders and are summarized below.

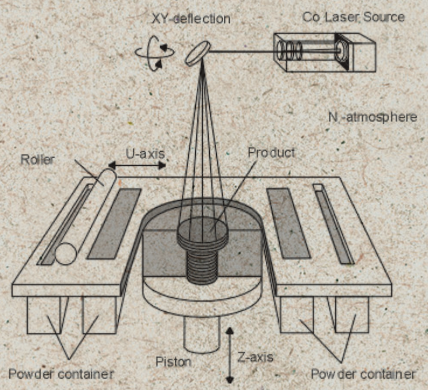
Stereolithography

Chuck Hull of 3D Systems, who pioneered rapid prototyping in the mid-1980s, is pictured in front of a stereolithography apparatus (SLA). Prototypes and parts are built from a liquid photopolymer, and each layer is created by a UV laser that cures one cross section at a time. At the end of the job, the whole part is cured once more after excess resin and support structures are removed.



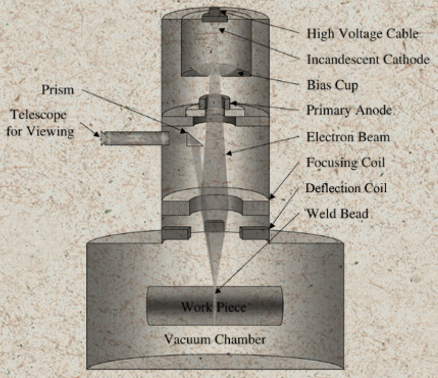
Laser Sinetring

Laser sintering machines build prototypes and final parts from powdered plastics and metals that are heated by a laser.



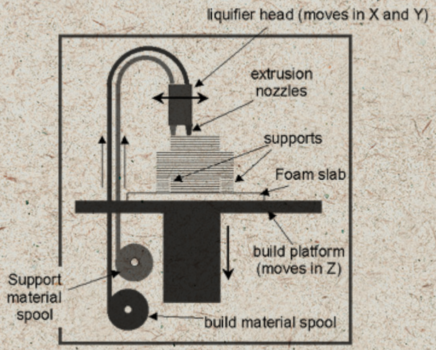
FUSED DEPOSTION MODELING (FDM)

FDM machines deposit ABS plastic or another type of thermoplastic through a heated nozzle to form the layers. After being extruded, the plastic solidifies. Developed by Scott Crump of Stratasys in the late 1980s, FDM is a popular technology for making prototypes



1-5-ELECTRON BEAM MELTING (EBM)

Using an electron beam that melts metal powder a layer at a time in a vacuum chamber, EBM machines are used to create titanium and cobalt chrome parts. Conventional machining may be required to finish the goods. These engine parts were made with Arcam's CAD to Metal system.



JETTING LIQUID POLYMER

Similar to inkjet printers, Objet's PolyJet piezoelectric print heads use thousands of nozzles to jet 16 micron layers of photopolymer that are immediately cured by UV light. The model material for the part and the support material that fills the voids come from different nozzles. Because of its 600x600 dpi resolution, PolyJet machines make fast prototypes.

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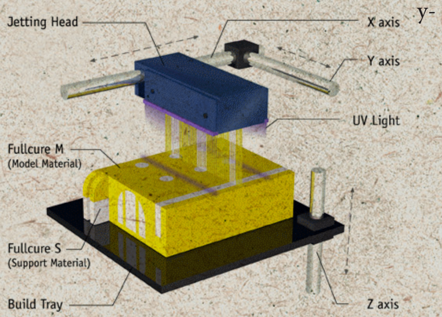
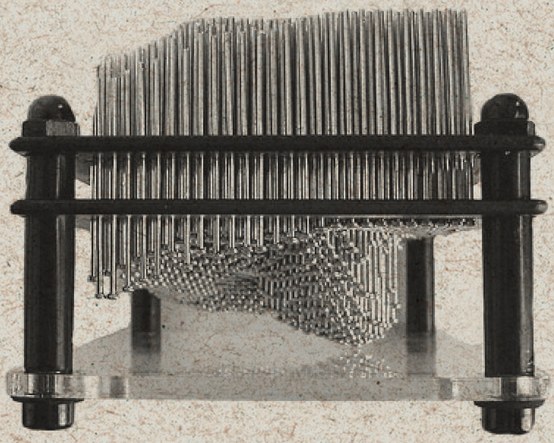


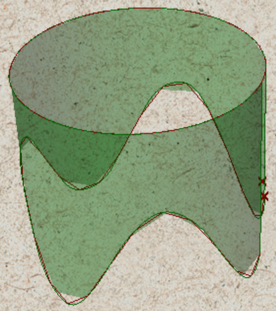
Vertical Layering

Additive manufacturing

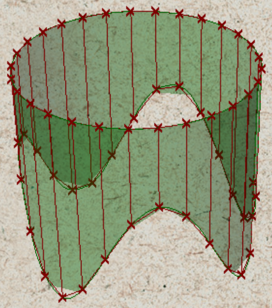
is defined as the "process of joining materials to make objects from 3D model data, usually layer upon layer.3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layers of material ,layers ranging from a millimeter to less than 1/1,000th of an inch. 3D printing is famous for being precise .All of the mentioned machines , are able to make very tiny object. Companies that are making these machines,consider the maximum precession one of their approaches .But if we don't need our machine for making small and detailed objects,then we can eliminate the layer-by-layer distribution of the granular material.This makes the process cheaper and possible with a wider range of granular material. With a vertical axis and computational control , we can push the nozzle to a certain point in the granular material and inject the binding material to create a voxel .The pressure of the sand makes it impossible to move the nozzle in any other direction than vertical axis . Therefore for printing two voxles with different X and Y coordination , the nozzle prints one of them ,move upward out of the sand , change the X and Y coordination and being pushed again for injecting the second one .

This can make the process very slow when printing large or high resolution object .But if all of the points that define the shape in 3 dimension would be sorted according to their X and Y coordination , it's possible to print all the points with same X and Y , in one insertion .In physical world , the neighbor voxels connect to each other , making a printed line , or column .Therefor in computational part ,instead of sending all of the points that define the object in 3 dimension to the machine ,we can transform the shape to a series of vertical lines , and provide the machine with start and end point of these lines. The machine pushes the nozzle to the starting point (the lower one) and deposit the binding material until it arrives to the end point (upper point)

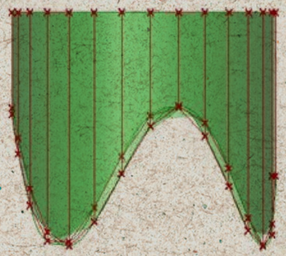




The model of the object



Transform the shape to vertical lines

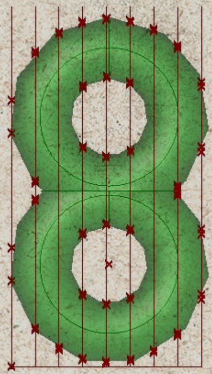


Extracting the start and end points of the lines

It's possible that the object has empty spaces inside . In this cases , some of the vertical lines that define the shape , would not be continuous.In this cases , abort and re-start the deposition while the nozzle is moving from start point to end point with a steady speed. These abortion and re-starting the deposition happens as much as it's necessary in one insertion process ,according to the form of the object .

A form with hollow spaces

intersecting the form with a grid of vertical lines



turning on and off the deposition according to positive and negative areas

Device : indoor , outdoor

Indoor (laboratory condition)

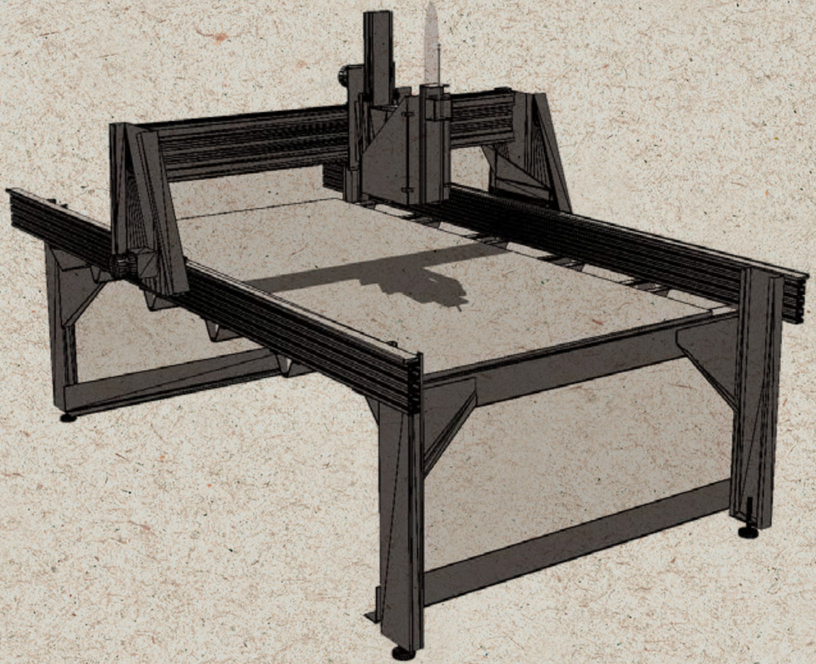
There can be different approaches to design a device that can 3D print with vertical layering method.And it's possible to categorize them from different point of views (scale , cost , precision, environmental affects, etc) .Our architectural background and the purpose of the Digital Tectonics studio , made us to develop and organize our thought and ideas about the device and it's possible applications in two main categories : The Indoor Device (Cartesian arm, a rectangular coordinates system) , and the Outdoor machine (a remote wheeled machine)

It's obvious that these requires different field of research with their own different technical obstacles . But they also have common technical and computational characteristics .Most of the studies about the device and the physical results that has been achieved during the past six months , are in small scale and in laboratory situation. But they illuminate many dark areas of our research , and gave us a more clear perspective of the potential further steps ,in both indoor and outdoor approaches.

In this part we are going to introduce the device that we made and used to create our experiments during the program. Also we are going to briefly describe our thoughts,ideas and speculations about the potential remote onsite device. Indoor : A costume

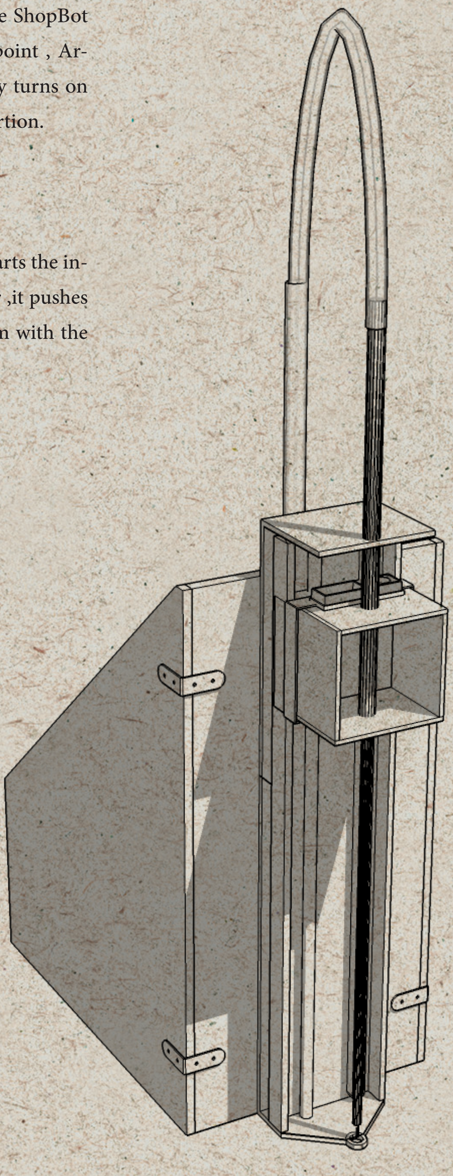
nozzle for a cnc machine

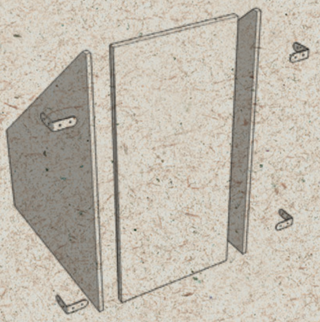
During the program , we focused on the lab device , a rectangular coordinates system. We take advantage of the ShopBot that is available in the institute for controlling the movements in X and Y axis . Because of the dimensional and geometric specifications of the ShopBot , it was not possible to use it's Z axis too .So we designed and made a device which can be attached to the head of the ShopBot , and controls the vertical movement and pumping system with an Arduino board .



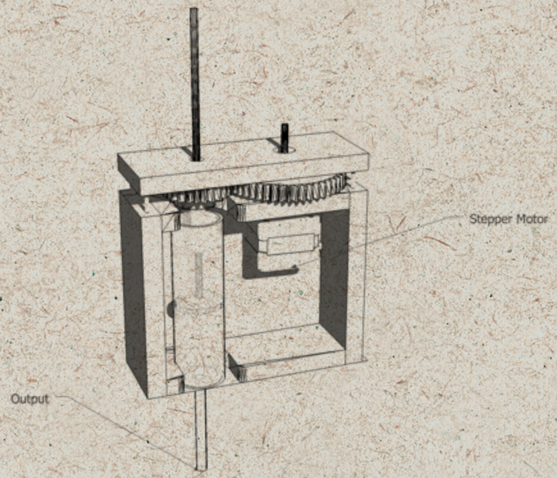
Two scripts, written in Processing and Arduino platform , are the central control , the brain of the whole process . A Grasshopper definition transforms the object to a G-code . This G-code file is being uploaded to the Processing script .The Processing script sends point by point , the X and Y coordinates to the ShopBot software, and the Z values of that point to the Arduino board after .The ShopBot moves to the received x and y coordinate .Just after it arrives to that point , Arduino pushes the nozzle to the first received Z coordinate and sequently turns on and off the pumping system , according to the next Z values of that insertion.

Each time the ShopBot receives a new at a certain point , the Arduino starts the injection process : Using the analog signals of an Infra-Red distance sensor ,it pushes the nozzle to the received Z value , and coordinates the pumping system with the vertical movement , according to the to the values from the G-code.

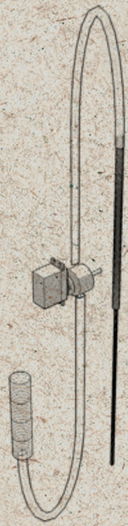




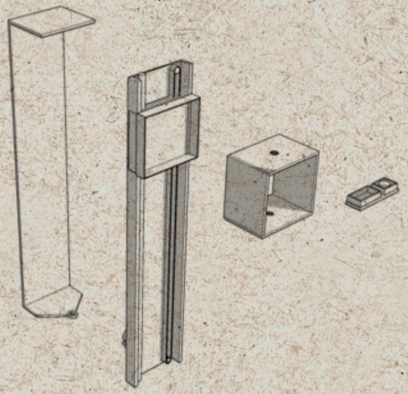
A wooden platform that has been designed according to the head of the Shop-Bot ,and can be connected to it with four screws .zz v



Pumping System : This part was one our main concerns during the program. We did tests with air pump and water pump .But we couldn't make a sufficient pumping system out of them,mostly because of the physical characteristics of the binding materials. But using the idea from of depositing system of homemade FDM 3D printers, our first tests with controlled pumping was done with this mechanism :



The last pumping system that we have attached to our device , is a very simple and small component , that gave us a better and easier control on the binding material depositing process.The pipe that is connecting the material storage to the nozzle , passes through the cylinder shape body of this component , goes around the interior surface and comes out from the other side. Inside , a small cylinder shape part , rotates by a Dc motor , and eventually pushes the fluid material through the nozzle , buy continuous squeezing of the pipe .This gives us the possibility to detach the binding material storage from the device , therefor solves the refilling process.



A printer axis for our vertical movement platform.The original Dc motor was re-placed with a stronger one , to achieve enough force for pushing the nozzle inside the sand.A Sharp low range Infra Red sensor made it possible to calculate the nozzle's position in Z axis ,with 10mm precision .The sensor sends analog signals (voltages) to the Arduino board according to it's distance from a horizontal plane that was implemented on top of the axis.These values then are being transferred to metric system.This ables the program to always compare the position of the nozzle inside the granulate material , with the Z values that are being received from the G-code.

Outdoor, A moving 3D Printer

This section is about the idea of implementing the vertical layering method on a remote controlled car . In theory ,this machine would be able to 3D print large scale objects and potentially architectural components in landscapes that are covered with a accountable deep layer of granular material ,specially deserts .It could be equipped with special 3d scanners that are being used in archeology field , there for it would be able to make simulation of the area , and 3D print emergent forms and spaces that are being affected by different natural parameters like wind , the main natural factor in desertification process. Further explanation about the the potential generative application of this device in deserts can be found in "Parametric Design " chapter.

Proving this idea and physically make the deceive requires some period of time that we didn't have in this program.But it doesn't require much time to understand the crucial features and specification that should be implemented on this device.Here are some of these issues that we assume we have to solve if we want to take this idea further :

1-Binding Material Storage : To 3D print large scale objects a large amount of the binding material is required .A tank that has the capacity for this amount of material , can not be attached to the remote device. The idea is that to have this tank on the truck that brings the remote device to the site. So the remote device can be connected to the material reservoir with a long pipe.

2- 3D print on a non-flat surface :To have a remote machine that can 3print with vertical layering method on the bumpy surface of the desert , it's crucial to design a mechanism that always keeps the nozzle in the vertical position.This can be done with a rotational system that changes the inclination of the nozzle ,with received data from a 3 axis tilt sensor .

3-Scaning system : We believe that this device should have a scanning system , to collect information about the topography of the site , and the depth of the granular material in each point.During a discussion with a group of archeologists in Barcelona , we got briefly familiar with some devices and technics to scan the surface and underground layers of a site.

Obviously this are just some of the major challenges to physically prototype this device , and for sure it requires hundreds of hours of research and seeking the council of expert in some fields , that are inevitably integrated with this project .

Maybe a good example of an existing device that gives an idea of how this remote machine could be , is Scarab , the NASA and Carnegie Mellon's Robotics Institute's collaborative lunar rover . It is an interesting case study for us , not only because of it's drilling system ,and it's off-road abilities , but also because of the clever suspension system that can keep the balance of the machine steep surfaces , like the dunes. The videos about this suspension system shows that it gives the machine the ability to incline to any direction , what makes it a possible mechanism for keeping the nozzle in vertical situation,though we don't have enough information yet to prove this.

M.3 Physical Test

M.3.1 Material Studies For Sand Solidification

_100 gr sand
_2units of water
_2 units of white glue
_result: After 24 hours, test 1 is not ready to deposite, it has a lot of glue over its top surface.

_100 gr sand
_2units of water
_1 units of white glue
_mixed
_result:After 24 hours, is almost ready to deposite. It has a lot of problems to mantain

100 gr sand
_2 units of water
_1/2 units of white glue not properly mixed
_result:After 24 hours, is almost ready to deposite. It has a lot of problems to mantain its shape.

_100 gr sand
_1 units of water
_1/2 units of white glue
_mixed
_result :After 24 hours, is almost ready to deposite. It has a lot of problems to mantain

pe.

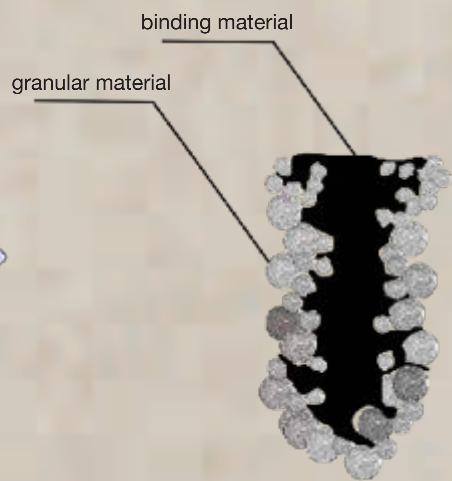
_100 gr sand
_2units of water
_3/4 units of clay (ceramic dough)
_result: After 24 hours,inside part of it is not dry,
but its surface shows a better reaction to mantain the

_100 gr sand
_4 units of water
_5 gr portland cement
_mixed
_result :After 24 hour. The test is not linked at all,
but shows a better result than the

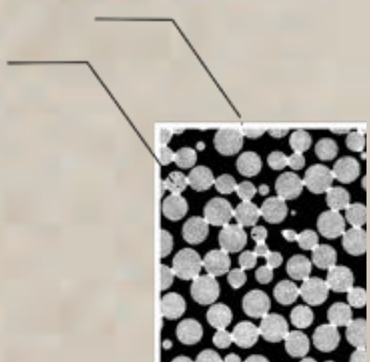
_100 gr sand
_5 units of water
_10 gr plaster _mixed
_result :After 24 hours, the test shows the best result to maintain the cohesion of the matter.

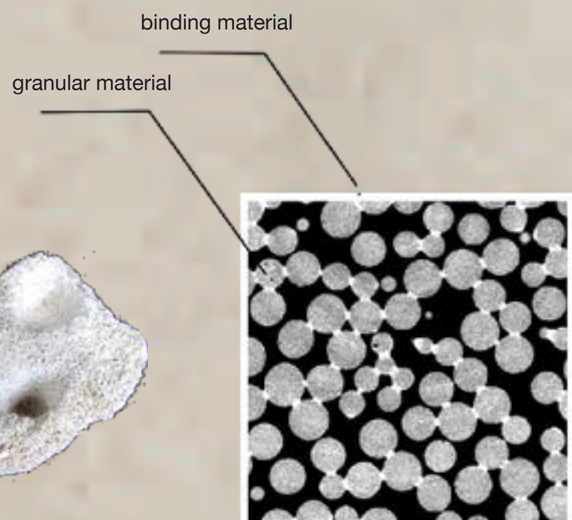
_100 gr sand
_4 units of water
_10gr plaster _mixed
_result :After 24 hours, the test shows the second best result
to maintain the cohesion of the

Effect of viscosity on material behavior



high viscosity plaster_granular material surfaces the binding material





low viscosity plaster_granular material absorbs the binding material

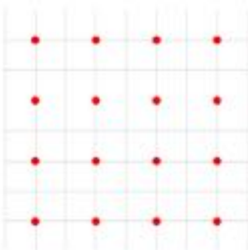
Point Injection
& Same Viscosity

Lineer Injection
& Different Viscosity

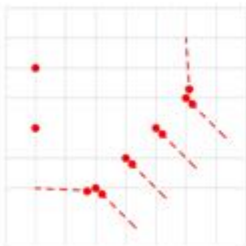
M.3 Physical Test

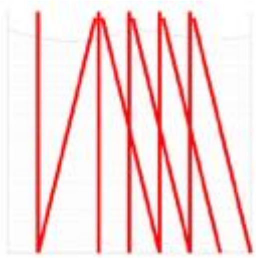
M.3.2 Manual Tests

path : 6 vertical injec-
tions
additive material :
%25 white glue & %75
water
proportion : 60ml per
injection

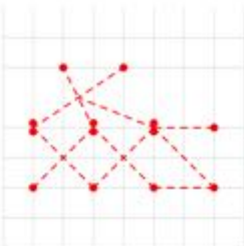


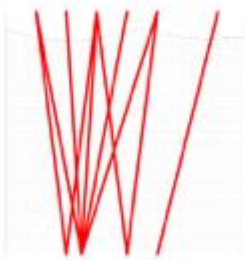
path : 4 x 4 array of
verticle injections
additive material : 40%
white glue & %60
water
proportion : 60ml per
injections



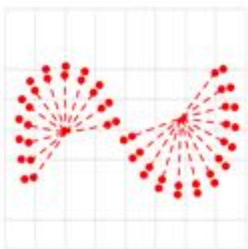


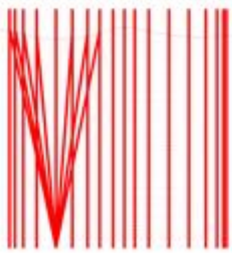
path : 12 injections (combination of verticle diagonal injec-tions)
additive material : resin (liquid plastic compound)
proportion : 20ml per injection



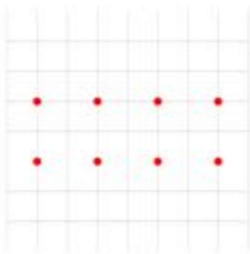


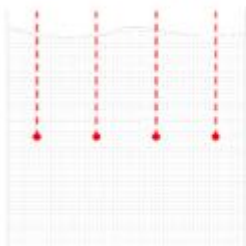
path : 13 injections (combination of diagonal injections)
additive material : resin (liquid plastic compound)
proportion : 10ml per injection





path : 50 injections (combination of diagonal and verticle injections)
additive material : %50 white glue & %50 water
proportion : 15ml per injection

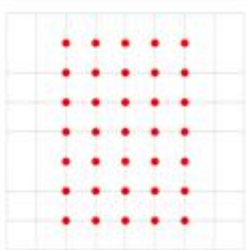


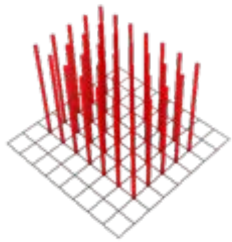


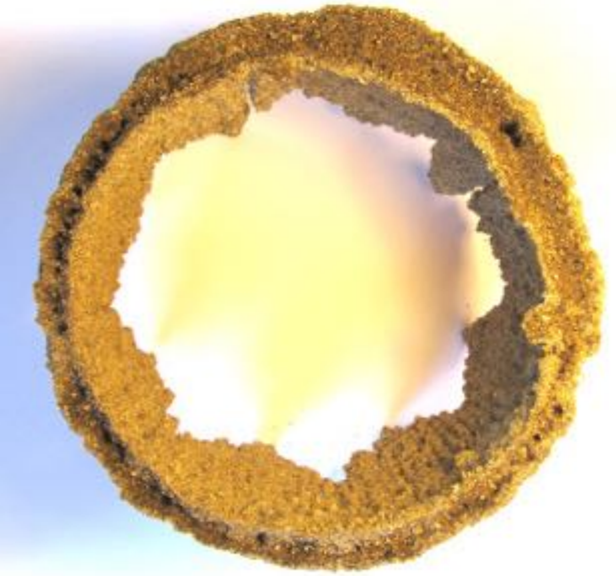
path : 8 continuously
point injections
binding material : %50
white glue & %50
water
proportion : 30 ml per
injection

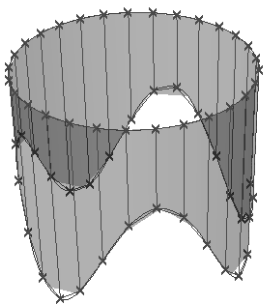
M.3 Physical Test

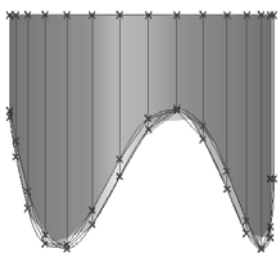
M.3.3 Machinic Tests

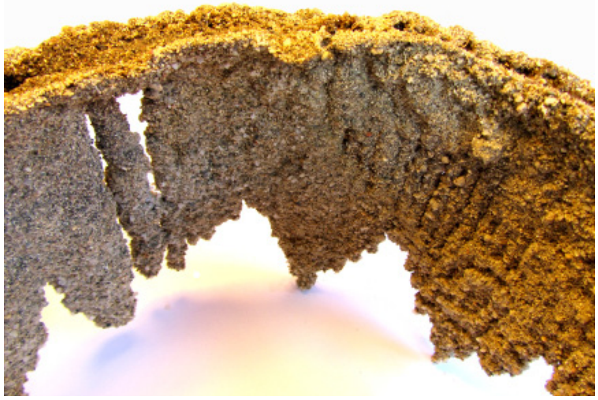












Design Parametric Principles

"The most important distinction in our changed notions of architecture design is the shift from geometry as an abstract regulator of the materials of construction to a notion that matter and material behaviors must be implicated in geometry itself. In the older models, the sovereign role of geometry was to regulate or impress itself upon the irrational and accidental condition of matter, thus measurement, proportion, and all of the elements of pure extension maintain a priority over that which they regulate. The new model must be understood not as a supercession of measuring but as the interplay between intensive and extensive differences."

Reiser+Umemoto

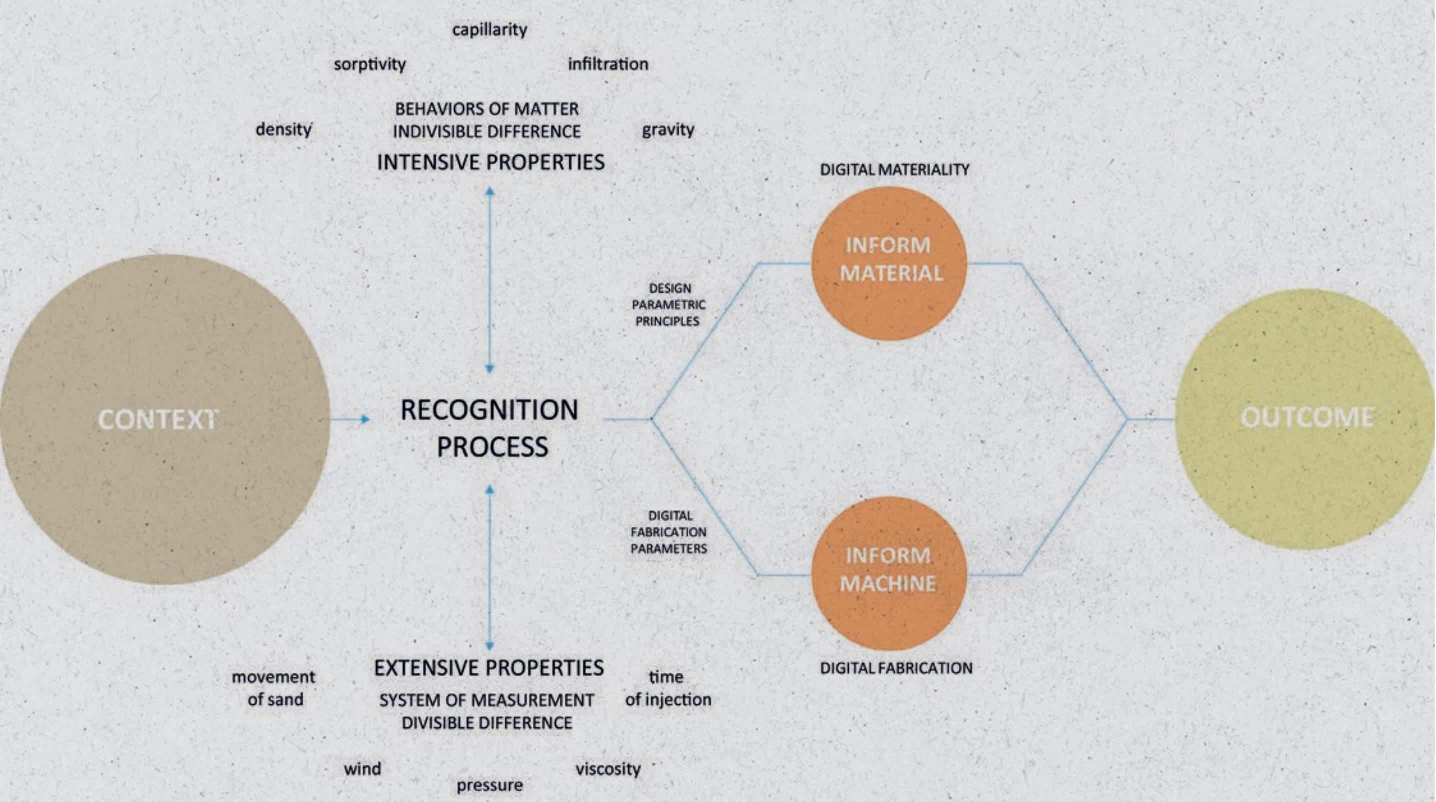
D.0 Material-based

Digital Materiality

Material +Machine Symbiosis

From the moment that we define our research field and we understand the main properties and behaviors of the material base we recognize the value of the material in itself, in order to generate a symbiosis between the machinic control and the physical reaction of the materiality. This physical association establishes a continuous interaction that generate unpredictable reactions, but that at the same time from there, emerge the beauty of the process in itself. The unpredictable is a reaction that emerges from a design operation defined by a specific data provided for the machine to the material.

Our symbiosis is base on the specificity of our technique: inject a fluid structural material into sand. The specific viscosity of the fluid, the location on the surface and into sand of the point of injection, the amount of material deposited, and to the other hand; the grain size, the angle of the surface and the different concentration of pressure into sand are the multiples variables that interact continuously to generate a symbiosis which allows us to achieve an specific outcome through the machinic control. All these variables together offer an uncertain design process, but on words of Gramazo&Kohler; “this obscurity seduces our senses, sending them on a voyage of discovery and inviting us to linger and reflect.”[1]


capillarity
sorptivity
infiltration
density
BEHAVIORS OF MATTER
INDIVISIBLE DIFFERENCE
gravity
INTENSIVE PROPERTIES
DIGITAL MATERIALITY
INFORM MATERIAL
DESIGN PARAMETRIC PRINCIPLES
CONTEXT
RECOGNITION PROCESS
OUTCOME
DIGITAL FABRICATION PARAMETERS
INFORM MACHINE
DIGITAL FABRICATION
movement of sand
EXTENSIVE PROPERTIES
SYSTEM OF MEASUREMENT
DIVISIBLE DIFFERENCE
time of injection
wind
pressure
viscosity

D.2 On Site Conditions_Proposal

Application scenario

Urban desertification

According to the Convention to Combat Desertification of the United Nations, desertification is a major economic, social and environmental problem of concern to many countries in all regions of the world.

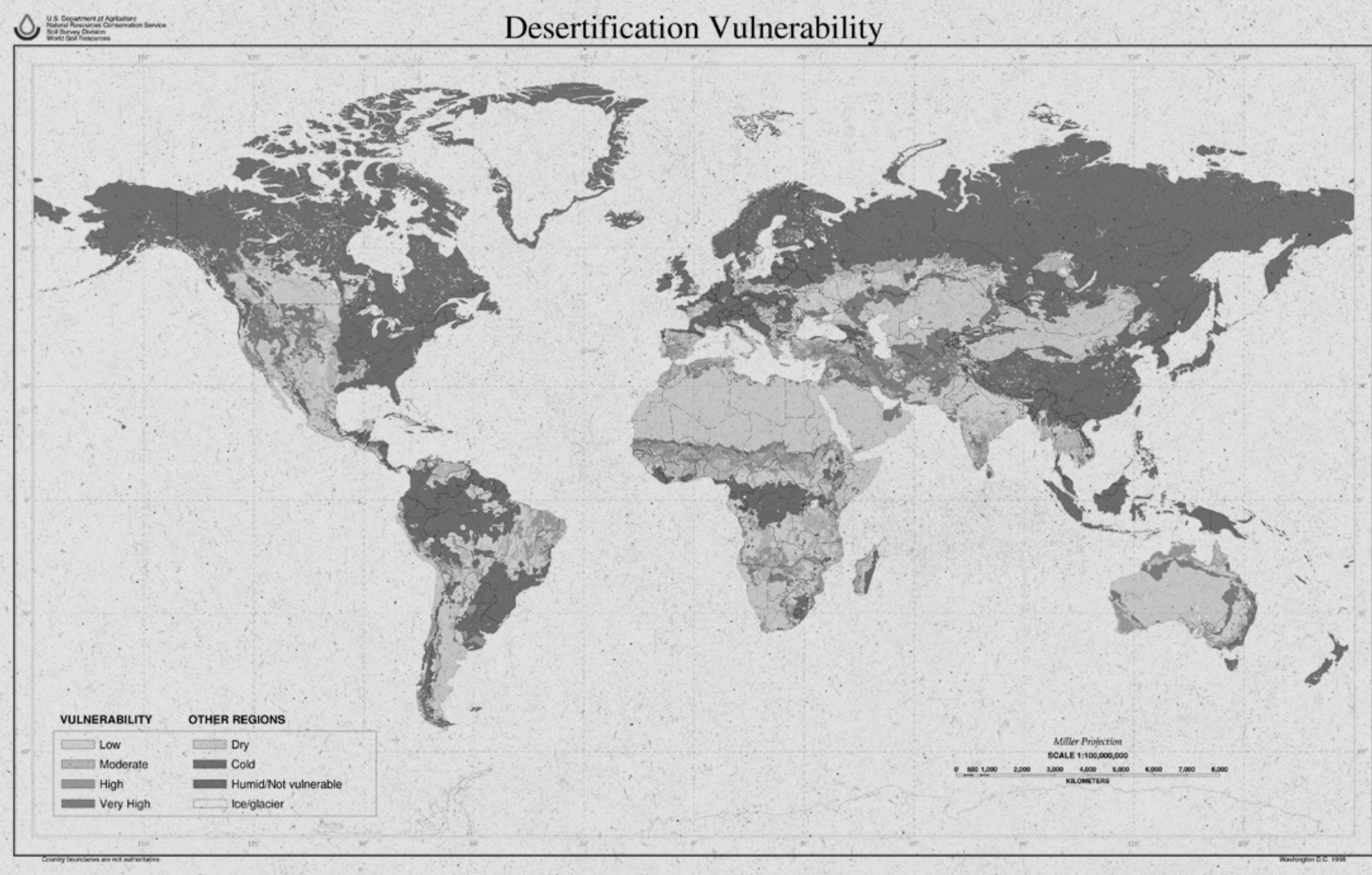
For instance, an estimated 6 million hectares of productive land are lost every year because of desertification, land degradation and declining agricultural productivity and it is estimated that US$42 billion is lost worldwide each year through desertification.[2]

Over 250 million people are directly affected by desertification and one billion people are at risk. These people include many of the world's poorest, most marginalized, and politically weak citizens.[3] Therefore the borders of the cities affected by urban desertification are increasing the potential for poverty and conflicts.

The situation is particularly harsh in Africa, where more than 50 percent of Africa's poorest people are concentrated on 'low potential' lands that are prone to degradation. More than two-thirds of the African continent is made up of drylands (43 percent drylands in addition to 27 percent classified as desert lands) and are home to more than 325 million people adapting to the uncertainties of climate and rainfall.[4]

We consider this real scenario as a potential real application for our research basically for two main considerations: one, the availability of sand should not a problem therefore this real problem is an opportunity for us, and two, on the base of DUNE project by Magnus Larsson[5], we can contribute to use our project to control urban desertification not to stop the problem creating a "wall" as Larson project, but using it as a source of design a strategy to protect a specific town or city affected by understanding the environment, the problem and at the end, use it as a source to generate social and urban benefits.

The idea is to propose an urban strategy to mitigate the consequences of this process, and create new uses on the urban borders. Then, embedded will be the digital materiality of our exploration.


U.S. Department of Agriculture
Natural Resources Conservation Service
Soil Survey Division
World Soil Resources
Desertification Vulnerability
VULNERABILITY
Low
Moderate
High
Very High
OTHER REGIONS
Dry
Cold
Humid/Not vulnerable
Ice/glacier
Miller Projection
SCALE 1:100,000,000
0 500 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000
KILOMETERS
Country boundaries are not authoritative.
Washington D.C. 1998

Urban Strategy

This real scenario should be settlement on cities with urban desertification problems. According to the United Nations, the most complicated urban places that are experience this issue are in Africa, a continent with several social problems such as hunger, undernourishment or poverty. We believe that this exploration might be interest to apply in cities in Africa in order to provide a scenario to use this proposal not only as a “barrier” or a urban development on the borders of a city, but to use it as a place to generate a virtuous cycle within the socioeconomically and urban reality understanding and using the environment of the place as a source of information for the final strategy.

Although there are many cities needed of solutions, we are going to consider only one of them as a representative model to apply the potentiality of our project.

Tsunami Concept

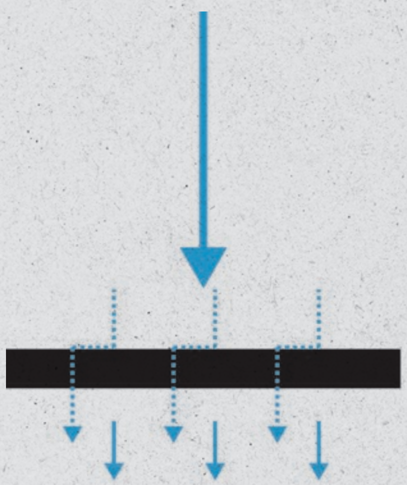
Our idea to implement a proper proposal on site to control desertification, we need to considerer the main factor that are embedded within the phenomena. Fundamentally, wind and the moving forward of dunes bit by bit are the main physical factors of the problem. The direction of the predominant and the speed of it wind are transcendental to understand the behavior of this movement and at the same time the type of dune that we are going to find on site. We think that stop the advance of dunes to

cities borders is not only impossible in fact is something that it does not understand the natural behavior of the environment. As an example, in Japan years ago, they build anti-tsunamis walls to control this huge nature force but using a strategy to stop it building a sort of barriers to confront the waves. As a result, last Japan's earthquake and tsunami, the barriers did not work properly and only one of them works.

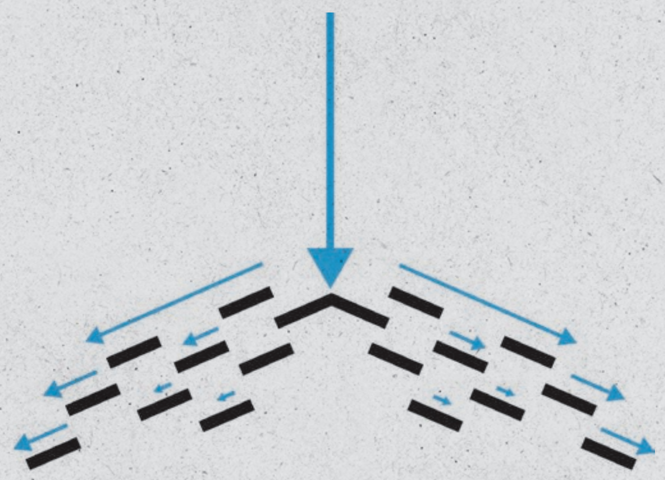
Through this comparison we do not want to put over the same level a tsunami with desertification, but we want to expose that understand a natural force of nature means try to control them, disperse or divert them rather than deny and try to make them disappear.

The idea is create an urban strategy which disperse and divert or redirect the predominant wind, therefore sand particles and the move forward of the dunes to the city and at the same time.

To achieve this goal, wind analysis is fundamental to understand the behavior of the predominant wind and to redirect it avoiding the urban places, thus build an intelligent sequence of "barrier" or "flaps" to control and generate new urban areas for the city. The intention is that these filter are not walls only, rather than are spaces, urban spaces and use the natural force to create benefits for the city, changing the conception of this problem to something that enrich the place.



BARRIER



FILTER- BARRIER

Redirection of wind urban strategy

As we mentioned before, the directions and intensity of wind is fundamental to understand the movement of the sand through arid lands and at the same time the behavior of dunes and surfaces where sand govern the landscape.

In these terms, understanding the motion of air (often called a flow field) around an object enables the calculation of forces and moments acting on the object. [6]

Our first question at stake is ¿how we can design a proposal that configures an understanding of the environment to disperse and divert the predominant wind behavior of this specific location?

The first image is related with wind tunnel analysis to have an illustration of this. ¿How wind reacts in front and around an object? As we can see on the diagram, wind react avoiding the object but try to return to its natural path, creating new physical behaviors, such as positive and negative pressures. Taking on consideration this, we propose a continuous system of filter-barriers to redirect the flow of the wind and sand outside the urban borders affected by desertification: The system in itself is acting as a network that bit by bit minimizes the force of wind, subtracting the energy embedded filtering and discomposing its intensity.

Surface information_context

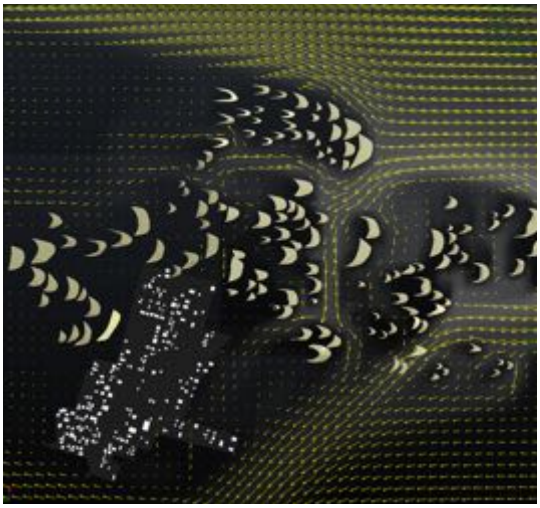
The urban strategy starts recognizing the environment implied at the location, taken the information of the advance and configuration of dunes plus the predominant wind. Therefore we consider the specific areas to implement our project following these rules creating a systematic sequence to redirect the wind far of the urban and agricultural places using the slopes of the dunes to inject the fluid structural material following the angles and the geometry of dunes. As we mentioned before, dunes have specific geometrical formations with clear patterns of behavior. Thus, Barchan dunes always have the same slope angle; between 10° to 12° wind slope and 34° inner slope, for instance.

The intention is identify the best areas to create the space-flap system using the same sand of the dunes, then, bit by bit the predominant wind are going to unveil, undress or uncover the underground structure.

As our machinic projection is to have a remote control device working on site, scan, read and process this information of the surface is fundamental to inform the machine where and how we are going to inject the fluid structural material depositions into sand. Thus, reading the data generated by the dune surface we can create the sense of architecture to the final outcome.

Space-flaps systems propose a sequence of public spaces and parks in order to create a green cordon to protect the city and give it news areas to use them as agricultural lands for instance.

Wind simulation



Vector field representing the direction and the speed of the turbulence created by the dunes

Recognition of the dunes that mostly are affecting the behavior of the wind and, by consequence, of the areas that are preserved from the dunes movement

Digital Tectonic

Underground information_context

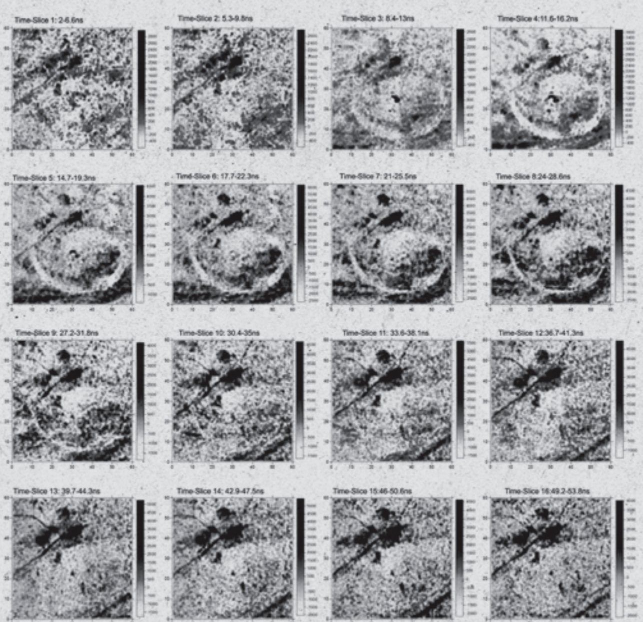
The physical rules of implied in sand allow us to recognize and identify its naturally grown organizational to interpret its internal order. The expression of the final outcome enriched by the digital information achieves a particular tectonic, generated through the machinic and parametric sequence of design.

If we use information extracted from dunes surfaces to discriminate areas to inject, underground environment provide us information to use it as a source of data to transform the materiality through this digital logic. Underground sand reality shows different levels of pressures and at the same time, in different scales. As we mentioned, sand behavior has an internal structure pilled high from microscopic chains and networks that generate multiples levels of pressures depending on the relationship of grains sand and the way that they are working together within this endless chain.

General speaking, typical sand dune section shows different sand stabilities. For example, near to the surface sand is "active" sharply defined dune morphology and going deep, sand stability is greater than above, as a consequence there are more pressure, but always with this unpredictable scenario that could present less pressure pockets.

These pockets, will generate the unpredictable scenario where depositions through capillarity will flow into sand using empty spaces in between sand particles, therefore we could infer that if the pocket has less pressure the behavior will be different if the flow advance through more pressure.

We can scan underground sand environment through different prospection techniques, thus collect the data to inform the machine the real scenario into sand. For instance, the Ground Probing Radar (GPR) geophysical surveying system is based in the ordinate emission to the subsoil of electromagnetic pulses of a known frequency and duration, and the recording of the reflections generated when they reach different layers and elements in the subsoil.[7]



Sequence of slices / Secuencia de cortes / Seqüència de talls

Foot notes

1 Gramazio, Fabio & Kohler, Matthias, “Digital Materiality in Architecture”, Lars Muller Publishers, Baden, Switzerland, 2008

2 United Nations Convention to Combat Desertification, http://www.unccd.int/

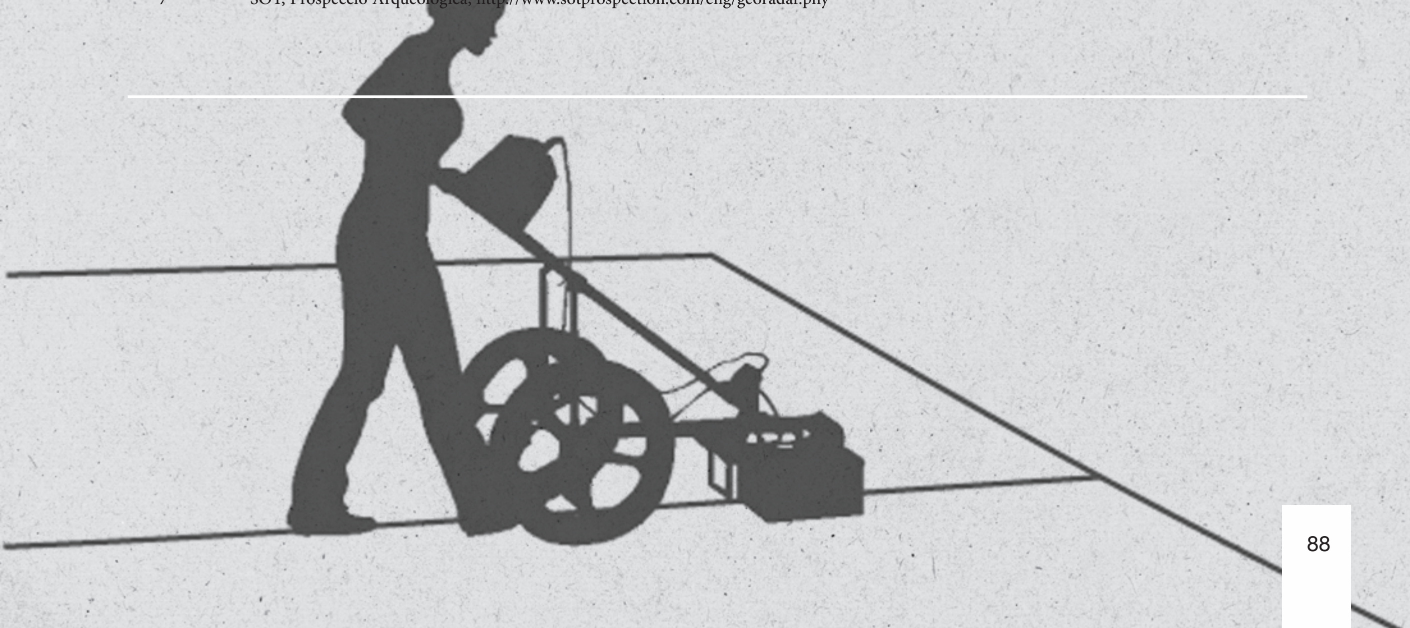
3 Ibid

4 Secretariat of the United Nations Convention to Combat Desertification, “HUMAN RIGHTS AND DESERTIFICATION Exploring the Complementarity of International Human Rights Law and the United Nations Convention to Combat Desertification”, Desertification, Land Degradation And Drought Issue Paper No. 1, © UNCCD 2008.

5 See T.1 References, DUNE (AA Thesis 07-08), Magnus Larsson

6 http://en.wikipedia.org/wiki/Aerodynamics

7 SOT, Prospecció Arqueológica, http://www.sotprospection.com/eng/georadar.phy



_Sand worldwide availability support the idea to use it as a base material on industrial and digital fabrication process, besides its multiples applications and versatility provide several options to consider sand as a sustainable and noble material.

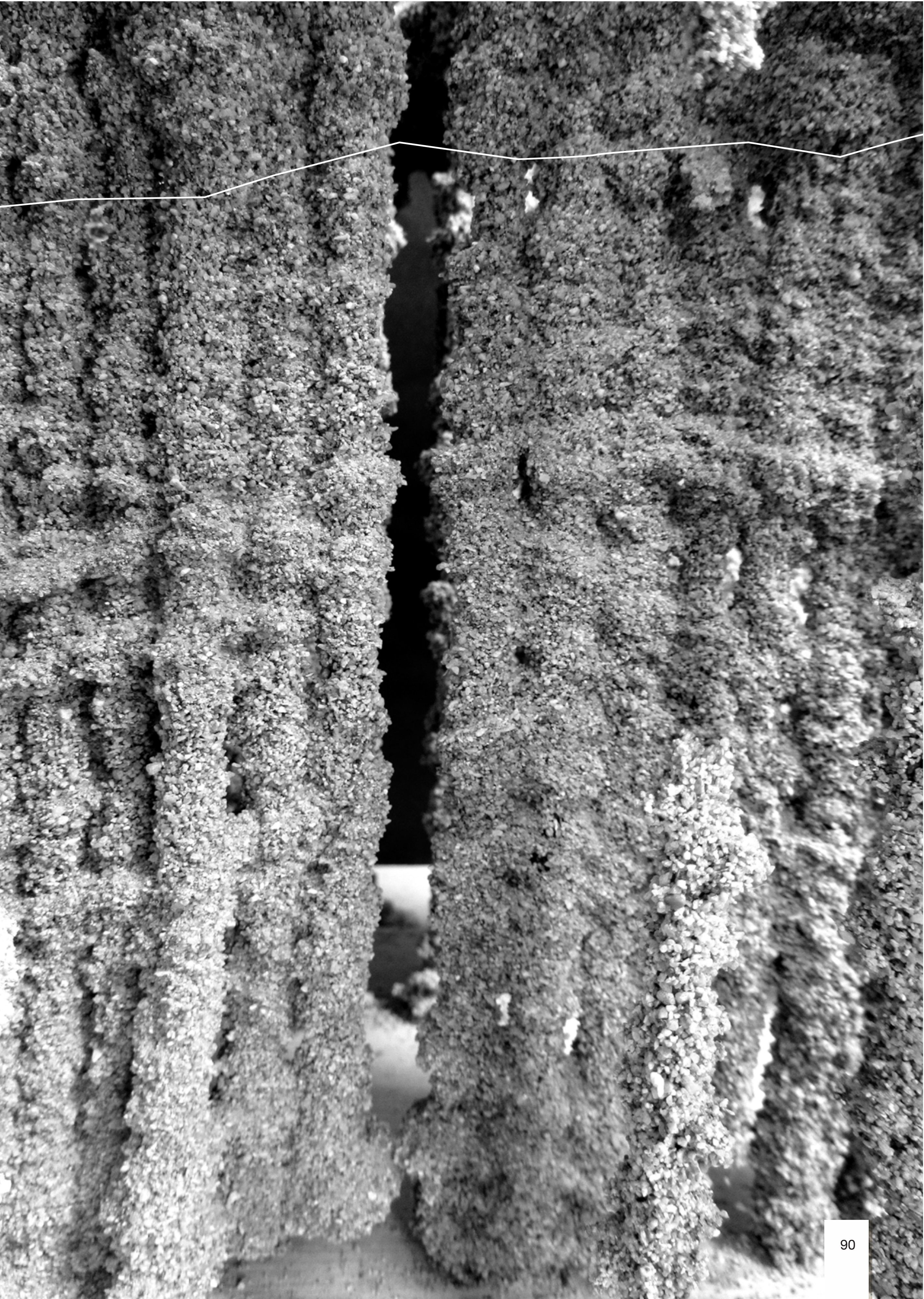
_ To inject a fluid with a certain viscosity value which flows into this granular material, allow us to use a low energy consumption through the process. Besides, does not produce waste material and in comparison with other 3d printer techniques, the base granular material is not toxic.

_This technique works in different scales, and it could be used to design from furniture or architectural components till architectural spaces and large scale landscape controlled by computational sequence.

_Our architectural background and the purpose of the Digital Tectonics studio, made us to develop and organize our thought and ideas about the device and it is possible applications in two main categories: The Indoor Device (Cartesian arm, a rectangular coordinates system) , and the Outdoor machine (a remote wheeled machine)

_It is possible to 3D print desirable large objects, without layer-by-layer distribution of the granular material, which is going to make the process faster, cheaper and possible with any granular material, and opens the possibility to create practical generative forms in specific sites.

_To 3d print on site use the environment as a base of the design process. Our projections to work with a remote wheeled machine, look for recognize the surface and underground of a specific context, scanning and processing its data to use it as a source of design operations.



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