Shapes of Gray: Concepts in Concrete

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Concrete is plastic and highly manipulatable. Its characteristics and the forms it takes are vastly diverse and its history as a building material is broken and nonlinear. By charting the trajectory of its manifestations and uses over time, as well as the trajectories of constituent things (chairs, pneumatic structures, blocks, and relevant artwork), I’ve reached an understanding of what some possible valuable futures for concrete might look like. I have proposed three of these possible futures in doodle form. The doodles appear later in this book.
WHAT

CONCRETE

IS
Concrete is the most abundant man-made substance on earth and is the most widely used building material. It is the definition of material and physical form as well as the definition of real. However, it remains a highly elusive building material with properties so varied that it is difficult to classify or describe its real architectural character. Its rapid and radical evolution, especially in contemporary practice, has broadened its horizons, giving each architect who uses it the power to define what it really is.
WHAT CONCRETE IS: THE PRODUCTS
Concrete's basic ingredients are water, aggregate, and cement. Aggregate is usually sand and gravel, but can be any inert material with compressive strength. Cement is a combination of lime, ash, and small amounts of many other chemicals. When water is added to the mixture of cement and aggregate, it triggers a chemical reaction that causes the cement to bond the aggregate together. The final, essential, and often overlooked ingredient to concrete is its formwork. Concrete has no inherent formal qualities. It takes on the form of whatever vessel it is poured into and adopts the surface treatment of its mold. This directly opposes Adolf Loos' statement in The Principle of Cladding that "Every material possesses a formal language which belongs to it alone and no material can take on the forms proper to another." Concrete has no formal language and depends completely on the formal logic of the materials of its formwork.
WHAT CONCRETE IS: THE FORMULA

CEMENT + AGGREGATE + WATER + FORMWORK = CONCRETE
All building materials require some level of processing before they can be used. Lumber has to be cut from trees, stones are cut from larger rocks, and steel has to be made from iron ore and forged into desired shapes. Concrete requires more processing than other building materials as each element of its mixture has to be processed and then added together in precise proportions to yield a desired concrete. Also, though aggregate is usually sand and gravel, nearly anything can be added to the cement and water mixture to create many diverse forms of concrete.
WHAT CONCRETE IS: MATERIAL PROCESSING

1. CUT
ROCK

1. CRUSH
2. MIX
3. CAST
4. CUT
CLAY

1. INJECT
2. HEAT
3. REDUCE
4. HEAT
5. REFINE
6. CAST
IRON ORE
WHAT CONCRETE IS: MATERIAL PROCESSING

1. CRUSH
2. MIX
3. GRIND
4. HEAT

1. CRUSH

1. CRUSH

1. FILTER

1. COMBINE

1. PROCESS
2. CONSTRUCT

CONCRETE
HISTORY OF CONCRETE
Adding to its enigmatic quality, concrete has a broken and nonlinear history. The ancient Egyptians used crude forms of it to build the pyramids, and it was an essential part of Ancient Roman architecture. When the Roman Empire fell, their recipe for concrete was lost, and it disappeared from building practice until around the early 19th century. Upon resurfacing as a building material, concrete was used to form canals, sewer systems, and boats. During the latter half of the 19th century, engineers and architects began to reinforce concrete with steel rebar. The tensile strength of the steel complimented the compressive strength of the concrete to create a more structurally sound and versatile material. In the 20th century, modern architects generally praised concrete for its neutrality and ability to make “abstract,” un-ornamented surfaces, complicated curves, and uniform floor slabs. In the 1930’s, German architects were able to achieve wafer thin shell structures by reinforcing concrete with fiberglass. In contemporary architecture, concrete’s properties are even more widely varied. By impregnating the mix with steel fibers, concrete can be made incredibly strong without the need for reinforcing rods. Architects and engineers are now experimenting with processes to make concrete lighter, change its color, and even change its opacity.
A HISTORY OF CONCRETE

EGYPTIANS USE CONCRETE AS MORTAR FOR BRICKS (2500 BC)

GREEKS DEVELOP NEW CONCRETE MIXTURES (600 BC)

ROMANS USE CONCRETE TO CREATE FORMS (75 BC)

THE ROMAN EMPIRE FALLS, AND THE RECIPE FOR CONCRETE IS LOST (475 AD)
JOHN SMEATON
REDISCOVERS CONCRETE

JOSEPH-Louis LAMBOT DEVELOPS STEEL-REINFORCED CONCRETE

CARL AKELEY DEVELOPS SHOTCRETE

EUGENE FREYSSINET DEVELOPS PRE-STRESSED CONCRETE
LE CORBUSIER DEVELOPS A NEW ARCHITECTURE USING CONCRETE

EERO SAARINEN DEVELOPS NEW FORMS IN CONCRETE

HEINZ ISLER DESIGNS THIN CONCRETE SHELLS

MASSIE ARCHITECTURE USES JIGSAW PUZZLE PIECES AS FORMWORK

1931 AD 1962 AD 1968 AD 2001 AD
A HISTORY OF CONCRETE

MARK WEST DEVELOPS FORM-DEDICATED FORMS

FIGURE 33

FUTURE BUILDINGS ARE PRINTED BY ROBOTS

FIGURE 32

EXISTING FORMS SERVE AS FORMWORK FOR NEW CONCRETE ARCHITECTURE
A HISTORY OF CHAIR DESIGN
Chairs, besides them being seating objects, often serve as microcosms of architecture. They can express architectural ideas on a small and intimate scale. Early man most likely sat on rocks and logs, and later, these materials were processed to better serve the function of seating. In the 19th century, some chair designs were standardized and mass-produced. In the 20th century, chairs became lighter and their structures became more efficient. At the Bauhaus, Marcel Breuer predicted that the structure of the chair would be reduced so much so that in the future, we would be sitting on columns of air. Though this hasn’t happened, there are inflatable chairs that are very light with minimal structure. Concrete chairs have also been made that are very light and strong.
A HISTORY OF CHAIR DESIGN

120,000 BC
EARLY MAN SITS ON STONES

2500 BC
EGYPTIANS CREATE ORNATE CHAIRS

1000 BC
ROMANS BEDS WERE ALL PURPOSE SEATING

1859 AD
MICHAEL THONET CREATES THE FIRST MASS PRODUCED CHAIR
VICO MAGISTRETTI DESIGNS THE MOST UBIQUITOUS CHAIR EVER

1967 AD

VERNER PANTON INVENTS THE FIRST INFLATABLE CHAIR

1960 AD

MARCEL BREUER CHARTS THE EVOLUTION OF THE CHAIR

1928 AD

MART STAM CREATES THE FIRST CANTILEVER CHAIR

1926 AD
TEJO REMY MAKES CONCRETE LOOK INFLATABLE

OMER ARBEL DESIGNS A LIGHTWEIGHT CONCRETE CHAIR

2009 AD

2010 AD

AS PREDICTED BY MARCEL BREUER, CHAIRS ARE COLUMNS OF AIR

FUTURE

PNEUMATIC STRUCTURES SERVE AS NEW FORMWORK FOR CONCRETE CHAIRS

FUTURE
A HISTORY OF PNEUMATIC STRUCTURES
Using air as the structure for a membranous wrapper is a lightweight and efficient way to create forms. The ancient Chinese began developing small hot air balloons made of paper for military purposes. Later, these hot air balloons were scaled up, and made big enough to transport people in. In the mid-20th century, Walter Bird began experimenting with using pneumatic structures as enclosures ranging in scale from houses to airplane hangars. This idea sparked much interest in the 1960’s. Buckminster Fuller experimented a lot with pneumatic structures not only as enclosures, but as lightweight structural supports too, with the membrane made of aluminum alloys. NASA was also interested in the efficiency of these structures, and began making Mylar balloons for satellites. The difficulty was that the membranes of these balloons could not be made strong enough to hold up against impacts from small meteorites. In the 1970’s, pneumatic structures were used often as enclosures for pavilions and temporary exposition spaces. Though pneumatic structures are still used today, the craze that surrounded them in the 60’s and 70’s eventually died away.
WALTER BIRD DEVELOPS PNEUMATIC STRUCTURES

THE MONTGOLFIER BROTHERS FLY A PASSENGER IN A HOT AIR BALLOON

NASA DEVELOPS NEW PNEUMATIC STRUCTURES
PNEUMATIC STRUCTURES ARE FOR PAVILIONS

1970 AD

PNEUMATIC STRUCTURES BECOME A NOVELTY

2000 AD

FUTURE

PNEUMATIC STRUCTURES SERVE AS ARMATURE FOR CONCRETE BLOCK CONSTRUCTION

FUTURE

PNEUMATIC STRUCTURES SERVE AS NEW FORMWORK FOR CONCRETE
A HISTORY OF CONCRETE BLOCKS
The ancient Egyptians used a crude form of concrete to adhere clay bricks together. Then the Romans perfected a concrete recipe, and began building forms with concrete alone. It wasn’t until the 1830’s, however, that blocks of concrete were cast and used in building construction. In the early 20th century, Frank Lloyd Wright made his own custom concrete blocks for use in several houses he designed. Recently, 3-d printing with concrete has become possible, and custom concrete bricks can be printed that, when aggregated, can create a diverse array of forms.¹¹
A HISTORY OF CONCRETE BLOCKS

1830 AD  
FIRST CONCRETE BLOCKS ARE USED

1900 AD  
HARMON S. PALMER DEVELOPS A NEW BLOCK-MAKING MACHINE

1923 AD  
FRANK LLOYD WRIGHT DESIGNS CUSTOM CONCRETE BLOCKS

1955 AD  
SUPERLITE MASS-PRODUCES CONCRETE BLOCKS
1965 AD
Concrete blocks account for 80% of wall construction.

2011 AD
Rael San Fratel-Lo uses 3D-printed concrete blocks.

Future
Pneumatic structure serve as armature for concrete block construction.
A HISTORY OF RELEVANT ARTWORK
In the 20th century, art began to overlap with and directly comment on architecture in thought-provoking ways. In 1965, Bruce Nauman cast the space under a chair to demonstrate the possibility of solidifying a perceived volume. In the 1970’s, Gordon Matta Clark began directly affecting and altering architecture by splitting and cutting holes through buildings, revealing new and unique spatial connections. Rachel Whiteread, launching off of Bruce Nauman’s piece, began casting the interior volumes enclosed by cabinets and houses. One of her most famous works, House, was made by filling the interior of a condemned house with concrete and then removing the house, revealing an exact cast of its interior volume.
BRUCE NAUMAN SOLIDIFIES THE SPACE UNDER A CHAIR 1965 AD

GORDON MATTA CLARK SPLITS A HOUSE 1974 AD

RACHEL WHITEREAD SOLIDIFIES THE ENCLOSED VOLUME OF A HOUSE 1993 AD

THE EXTERIOR VOLUME OF A HOUSE IS SOLIDIFIED IN A CONCRETE SHELL FUTURE

FIGURE 57

FIGURE 58

FIGURE 59
PROPOSITIONS FOR FUTURE CONCRETE
With such a rich and diverse history, the future of concrete is broad. In understanding where concrete fits into the histories of constituent things (chairs, pneumatic structures, artwork), I contend that three valuable and very plausible futures of concrete are:

I. Pneumatic-formed concrete, using new concrete with added tensile strength so as to enable more diverse form making

II. Lo-tech, fabric-formed, pneumatically supported concrete modules that can aggregate into different shell structures

III. Cast-in-place concrete shells over forms that no longer serve their function and can be removed from the cast to yield useful architectural void spaces
PROPOSITIONS FOR FUTURE CONCRETE

2500 BC
Concrete as mortar for bricks

1756 BC
Concrete as form with formwork

1848 AD
Reinforced concrete as form with formwork

120,000 AD
Stone as seat

1783 AD
Pneumatic structure as carrier

1926 AD
Optimized structure as seat
PROPOSITIONS FOR FUTURE CONCRETE

1911 AD
SHOTCRETE AS FORM WITH 1-SID-ED FORMWORK

2008 AD
CONCRETE AS FORM WITH FABRIC AS FORMWORK

FUTURE
PRINTED CONCRETE REQUIRES NO FORMWORK

FUTURE
PROPOSITION I: SHOTCRETE WITH EXISTING FORM AS FORMWORK

1960 AD
PNEUMATIC STRUCTURE AS SEAT

2009 AD
LIGHTWEIGHT CONCRETE AS SEAT

FUTURE
AIR AS SEAT

FUTURE
PROPOSITION II: CONCRETE WITH PNEUMATIC FORMWORK AS SEAT

1941 AD
PNEUMATIC STRUCTURE AS ENCLOSURE

FUTURE
PROPOSITION II: CONCRETE WITH PNEUMATIC FORMWORK AS SEAT

FUTURE
PNEUMATIC STRUCTURE AS TEMPORARY STRUCTURE FOR CONCRETE BLOCKS
PROPOSITIONS FOR FUTURE CONCRETE

1830 AD
CAST CONCRETE BRICKS
PROPOSITIONS FOR FUTURE CONCRETE

PROPOSITION II:
CONCRETE WITH PNEUMATIC FORMWORK AS SEAT

FUTURE
PNEUMATIC STRUCTURE AS TEMPORARY STRUCTURE FOR CONCRETE BLOCKS

1941 AD
HOUSE AS FORMWORK FOR CONCRETE SHELL

FUTURE

1955 AD
MASS-PRODUCED CAST CONCRETE BRICKS

2011 AD
PRINTED CONCRETE BRICKS

1993 AD
HOUSE AS FORMWORK FOR VOLUME OF INTERIOR

FUTURE
MASS-PRODUCED CAST CONCRETE BRICKS

PRINTED CONCRETE BRICKS

FUTURE
HOUSE AS FORMWORK FOR CONCRETE SHELL
Pneumatic-formed concrete chair:

Air is the structure of an inflatable chair. I will demonstrate the ability to use pneumatic structures as formwork for cast-in-place concrete architecture by casting fiberglass-reinforced concrete over an inflatable chair and then deflating the chair, leaving a concrete shell bearing the form of the chair.
fabric-formed concrete modules:

Since concrete is highly manipulatable, it can be very expressive. By handcrafting concrete modules that key together and aggregate into various shell forms, I can create a façade system that shows its handedness, and can be implemented architecturally on a large scale. Pneumatic structures can be used as temporary structure for this cladding system.
PNEUMATIC STRUCTURE

MODULAR KIT

FABRIC-FORMED, STEEL FIBER REINFORCED CONCRETE
Things that no longer serve their function, but still have valuable architectural forms can be used as formwork for concrete shell casts. A condemned house can be covered in concrete, and the house could be removed from the inside after the concrete sets. This will yield a concrete shell with an interior volume that is the exact form of a house.
EXISTING HOUSE AS FORMWORK

LOST HOUSE, CAST-IN-PLACE

FIBERGLASS REINFORCED GUNITE
PROPOSITIONS FOR FUTURE CONCRETE: PROPOSITION III

- NORTH AMERICA
- NEW ENGLAND
- NEW YORK
- HUDSON VALLEY
I propose designing a house in the Hudson River Valley that can support a self-sufficient, pastoral/artisanal lifestyle for a contemporary couple. William is a writer and editor, as well as a beekeeper, whisky distiller, and cheese maker. Jessi designs graphics, websites, and apps, and is an avid home-brewer, pickler, and reader.

Their house will include facilities for farming, beekeeping, cheese making, beer brewing, whisky distilling, and bread making, and will have studios for writing and design. The house's character will be derived from serving these food and drink production functions. Situated in the Hudson River Valley, William and Jessi will be close enough to New York City to support their careers as a writer and designer, but will still be able to live autonomously and lightly off of the land.
Most of the research I’ve done has been in the form of directly testing concrete’s properties and characteristics. From the beginning of the semester, I’ve been exploring the relationship between concrete and its formwork. In addition to experimenting with different concrete mixtures, I started by painting with concrete (page 51) and making concrete forms that express concrete’s uniformity and homogeneous makeup (pages 52-53). I tried casting concrete without using external formwork (page 49), and started experimenting with using pneumatic structures as the formwork for concrete (pages 56-58). Through researching by doing, I got a good, hands-on grasp on what concrete is capable of.
I made these works by saturating fabric with concrete and hanging it to dry. They demonstrate a way to construct concrete forms without using external physical formwork.
I added graphite to a concrete mold and it imprinted on the concrete when it set.

I used fabric dye to color the sand in concrete to make it pink.

I used sawdust as an aggregate to yield a concrete panel 20% lighter than typical concrete.

I used foam blocks as an aggregate to yield a concrete panel 30% lighter than typical concrete.
THIS PAINTING IS BLACK UNTITLED (1948) BY WILLEM DE KOONING

THIS IS A REPLICA OF WILLEM DE KOONING’S PAINTING THAT I MADE USING BLACK AND WHITE QUICK-SETTING CONCRETE

I APPLIED PINK CONCRETE TO THIS CANVAS USING A PAINT ROLLER. THE FORM OF THE CONCRETE WAS DETERMINED BY THE PROPERTIES OF THE ROLLER

I APPLIED CONCRETE TO THIS CANVAS USING A PAINTBRUSH. THE FORM OF THE CONCRETE WAS DETERMINED BY THE BRUSHSTROKES USED
**REBAR MESH IS ADDED OVER THE CONTOURS OF EXISTING DIRT MOUNDS**

**A MIX OF SAND, GRAVEL, CEMENT, WATER, AND BLUE DYE IS POURED OVER THE DIRT**

**THE DIRT IS EXCAVATED FROM WITHIN THE SHELL**

**A HABITABLE CONCRETE SHELL BEARING THE FORM OF THE DIRT MOUND REMAINS**
Light tubes and door frames are added to an existing sand dune.

A mix of sand, cement, water, and red dye is poured over top of the sand dune.

The sand is excavated from within the shell.

A habitable concrete shell bearing the form of a naturally existing sand dune remains.
A pneumatic structure is inflated.

A mix of cement, sand, and dye is poured over top.

The pneumatic structure is deflated, yielding a habitable interior.
A pneumatic structure is inflated.

A mix of cement, sand, and dye is poured over top.

The pneumatic structure is deflated yielding a habitable interior.
A PNEUMATIC STRUCTURE IS INFLATED

A MIX OF CEMENT, SAND, AND DYE IS POURED OVER TOP

THE PNEUMATIC STRUCTURE IS DEFLATED YIELDING A HABITABLE INTERIOR


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