Shapes of Gray: Concepts in Concrete

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SHAPES OF
GRAY:
CONCEPTS IN
CONCRETE

FORD BOSTWICK
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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.
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

ROCK → 1. CUT → STONES

 TREES → 1. CUT
 2. DRY
 3. CUT → LUMBER

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

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

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

1. CRUSH

1. FILTER

1. COMBINE

1. PROCESS
2. CONSTRUCT

1. COMBINE

LIMESTONE

ROCK

AGGREGATE

CEMENT

WATER

WATER

MATERIALS

FORMWORK
A 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

GREEKS DEVELOP NEW CONCRETE MIXTURES

ROMANS USE CONCRETE TO CREATE FORMS

THE ROMAN EMPIRE FALLS, AND THE RECIPE FOR CONCRETE IS LOST
A HISTORY OF CONCRETE

JOHN SMEATON
REDISCOVERS CONCRETE

JOSEPH-Louis LAMBOT DEVELOPS STEEL-REINFORCED CONCRETE

CARL AKELEY DEVELOPS SHOTCRETE

EUGENE FREYSSINET DEVELOPS PRE-STRESSED CONCRETE

FIGURE 24  1756 AD
JOHN Smeaton Rediscovers ConCretE

FIGURE 25  1848 AD
Joseph Louis Lambot Develops Steel-Reinforced ConCretE

FIGURE 26  1911 AD
Carl Akeley Develops ShotCretE

FIGURE 27  1927 AD
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
2008 AD
MARK WEST DEVEL-
OPS
FAB-
RIC-FORMED CON-
CRETE

FUTURE
BUILDINGS ARE
PRINTED BY
ROBOTS

FUTURE
EXISTING FORMS
SERVE AS FORM-
WORK FOR NEW
CONCRETE ARCHI-
TECTURE
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

EARLY MAN SITS ON STONES
120,000 BC

EGYPTIANS CREATE ORNATE CHAIRS
2500 BC

ROMANS BEDS WERE ALL PURPOSE SEATING
1000 BC

MICHAEL THONET CREATES THE FIRST MASS PRODUCED CHAIR
1859 AD
MART STAM creates the first cantilever chair

1926 AD

MARCEL BREUER charts the evolution of the chair

1928 AD

VERNER PANTON invents the first inflatable chair

1960 AD

VICO MAGISTRATI designs the most ubiquitous chair ever

1967 AD

FIGURE 38  FIGURE 39  FIGURE 40  FIGURE 41
Tejo Remy makes concrete look inflatable as predicted by Marcel Breuer, chairs are columns of air.

Omer Arbel designs a lightweight concrete chair.

Pneumatic structures serve as new formwork for concrete chairs.

A History of Chair Design 21
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.
CHINESE DEVELOP HOT AIR BALLOONS

THE MONTGOLFIER BROTHERS FLY A PASSENGER IN A HOT AIR BALLOON

WALTER BIRD DEVELOPS PNEUMATIC STRUCTURES

NASA DEVELOPS NEW PNEUMATIC STRUCTURES
A HISTORY OF PNEUMATIC STRUCTURES

FIGURE 19
1970 AD
PNEUMATIC STRUCTURES ARE FOR PAVILIONS

FIGURE 20
2000 AD
PNEUMATIC STRUCTURES BECOME A NOVELTY

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
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
A HISTORY OF CONCRETE BLOCKS

FIGURE 55

1965 AD

Concrete blocks account for 80% of wall construction.

FIGURE 56

2011 AD

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

FUTURE

Pneumatic structures 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

GORDON MATTA CLARK SPLITS A HOUSE

RACHEL WHITEREAD SOLIDIFIES THE ENCLOSED VOLUME OF A HOUSE

THE EXTERIOR VOLUME OF A HOUSE IS SOLIDIFIED IN A CONCRETE SHELL
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
REINFORCED CONCRETE AS FORM WITH FORMWORK

CONCRETE AS MORTAR FOR BRICKS

1756 BC

STONE AS SEAT

120,000 AD

OPTIMIZED STRUCTURE AS SEAT

1926 AD

PNEUMATIC STRUCTURE AS CARRIER

1783 AD

CONCRETE AS FORM WITH FORMWORK

1848 AD
PROPOSITIONS FOR FUTURE CONCRETE

1911 AD
SHOTCRETE AS FORM WITH 1-SIDED 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

FUTURE

FUTURE

PNEUMATIC STRUCTURE AS TEMPORARY STRUCTURE FOR CONCRETE BLOCKS
1830 AD

CAST CONCRETE BRICKS
PROPOSITION II:
CONCRETE WITH PNEUMATIC FORMWORK AS SEAT
FUTURE
PNEUMATIC STRUCTURE AS TEMPORARY STRUCTURE FOR CONCRETE BLOCKS

PROPOSITION III:
PNEUMATIC STRUCTURE AS TEMPORARY STRUCTURE FOR CONCRETE BLOCKS
FUTURE
PRINTED CONCRETE BRICKS

1955 AD
MASS-PRODUCED CAST CONCRETE BRICKS

2011 AD
PRINTED CONCRETE BRICKS

1993 AD
HOUSE AS FORMWORK FOR VOLUME OF INTERIOR

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.
PNEUMATIC FORMWORK

CAST-IN-PLACE

FIBERGLASS REINFORCED CONCRETE
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
lost-house shotcrete shell cast:

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 RIVER 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.
RESEARCH AND DEVELOPMENT
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 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.

I used fabric dye to color the sand in concrete to make it pink.
THIS PAINTING IS BLACK UNTITLED (1948) BY WILLEM DE KOONING

THIS IS A REPLICATION 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
THING 1
THING 2
THING 3
THING 4
THING 5
THING 6
THING 7
THING 8
THING 9
THING 10
THING 11
THING 12
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 DEFATED 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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