Creases and Folds: Applying Geometry to a Pop-Up Fashion Pavilion

by

Yujing Li

Submitted to the Department of Architecture
in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Art and Design
at the
Massachusetts Institute of Technology

June 2010

Signature of Author..

Department of Architecture
May 22, 2009

Certified by ....

J. Meejin Yoon
Associate Professor of Architecture
Thesis Supervisor

Accepted by ....

Les Norford
Professor of Architecture
Chairman of the Undergraduate Curriculum Committee

Thesis Supervisor

J. Meejin Yoon
Associate Professor of Architecture

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ABSTRACT

This thesis explores the architectural opportunities embedded in geometric folding by studying the limitations and possibilities of a variety of patterns. In particular, the thesis focuses on the Yoshimura or diamond folding pattern. By manipulating specific rules guiding the diamond fold, the surface can be adapted to enclose a variety of volumes for different programs. The adaptations of the diamond fold rules are tested in a design for a pop-up fashion pavilion. The result is a geometric form that acts as a canopy, enclosure and inhabitable surface to hold program elements such as a marketplace, small fitting rooms, and a runway.

THESIS SUPERVISOR: J. Meejin Yoon
TITLE: Associate Professor of Architecture

ACKNOWLEDGMENTS

To my parents for their support and advice

To archfamily for keeping a smile on my face

To Robert and Bill for being the best cheerleaders

To Meejin for always challenging me

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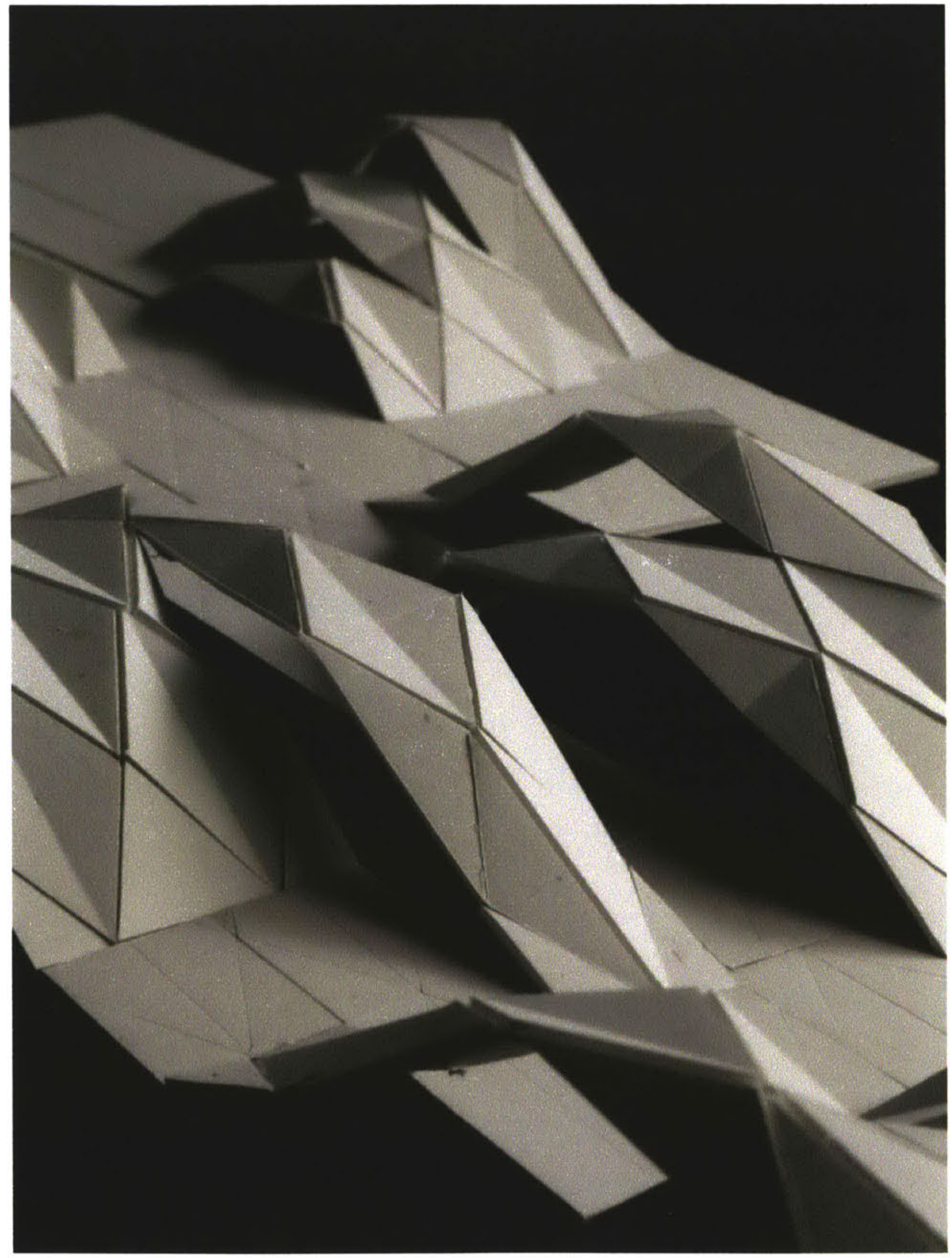
INTRODUCTION

The first half of my thesis semester was spent researching geometric folding, their rules and patterns, and also how they can be applied architecturally and spatially. The initial explorations simply involved folding mathematical patterns with bristol paper and observing their behavior at different states of folding and unfolding. However, it soon became apparent that these studies did not suggest any architectural qualities and remained only paper objects and surfaces. My research then turned to how the surfaces and patterns could be manipulated, mutated, activated to create sectional and volumetric variety, facades, or adaptable walls.

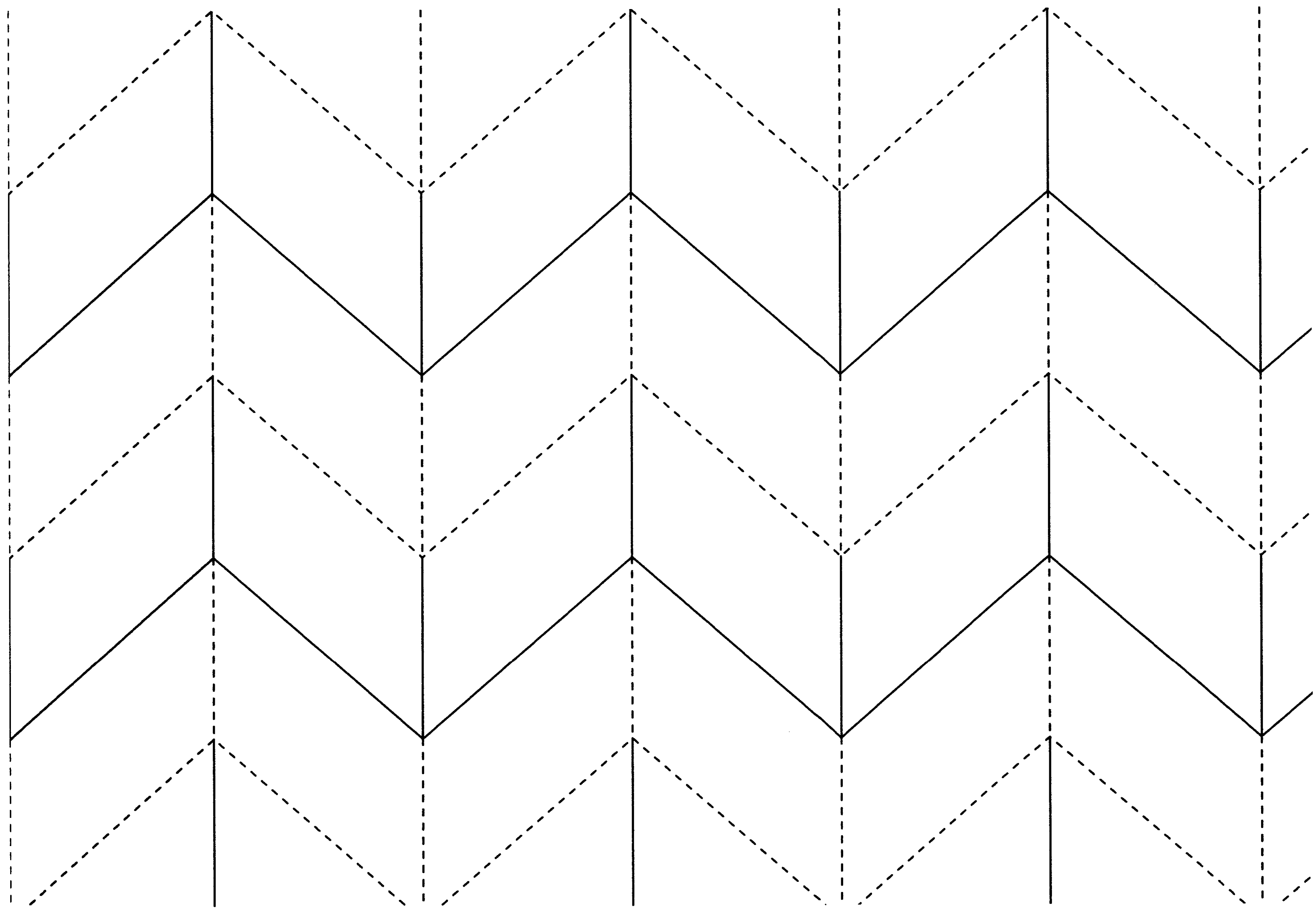
The cataloging of pure mathematical folding forms allowed me to discover the advantages and disadvantages of each system, while the research of the folding manipulations provided the basis of the design proposal.



RESEARCH

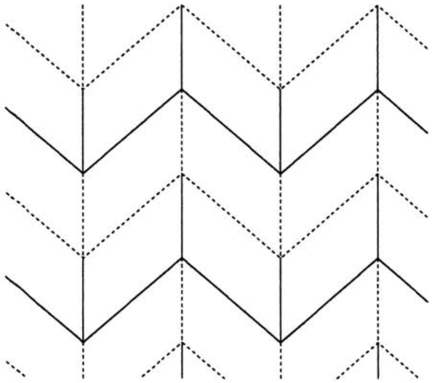
- Folding Catalog
  - Accordion Patterns
  - Protruded Patterns
  - Hybrid Patterns

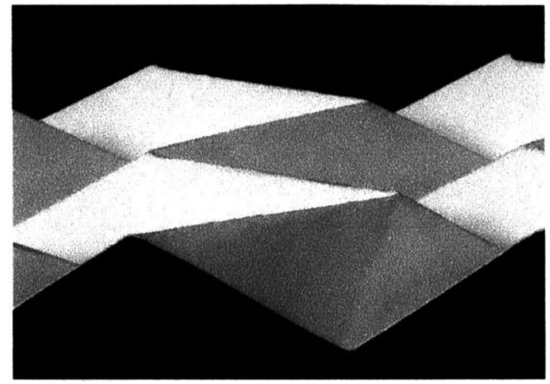
- Pattern Manipulations
  - Scale
  - Hard/Soft
  - Cinching
  - Pop In/Pop Out



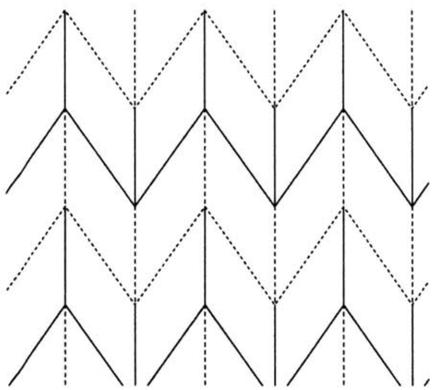
ACCORDION FOLD

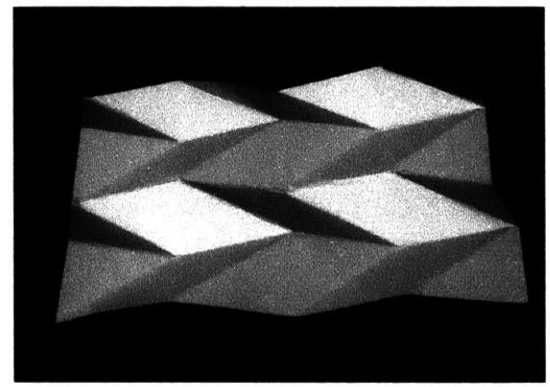
MUIRA ORI PATTERN



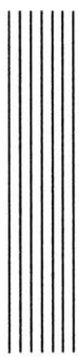


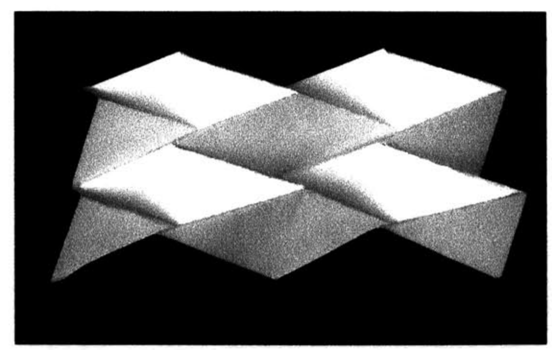
unfolded surface area: 100%



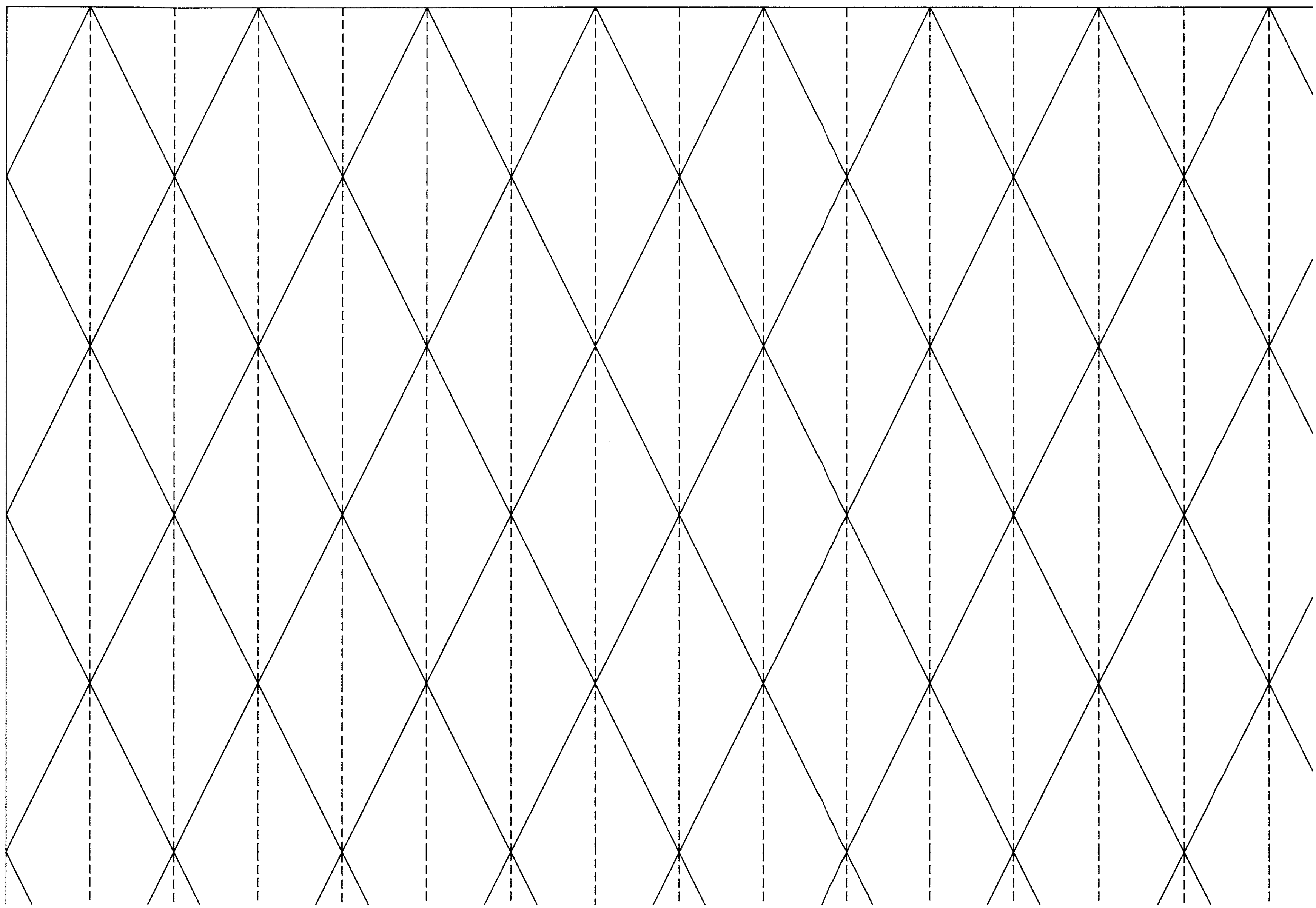


partially folded surface area: 50%

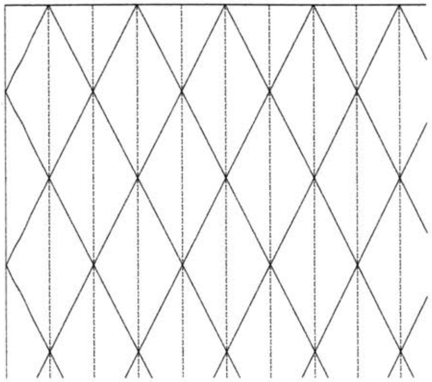


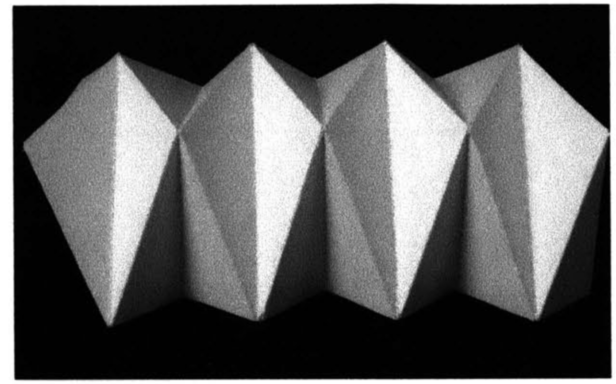


folded surface area: material thickness x number of ribs



DIAMOND PATTERN





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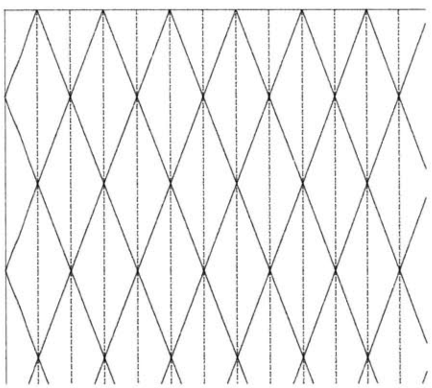

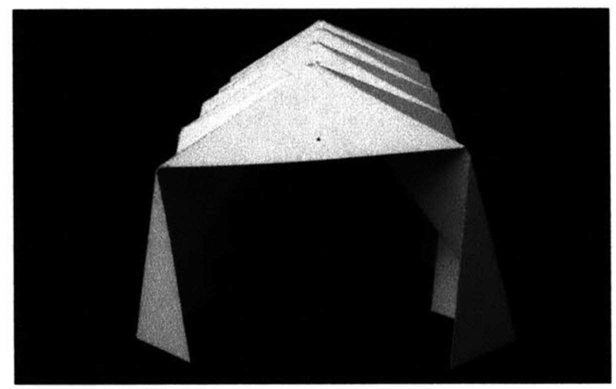

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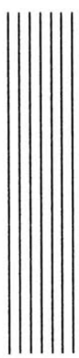
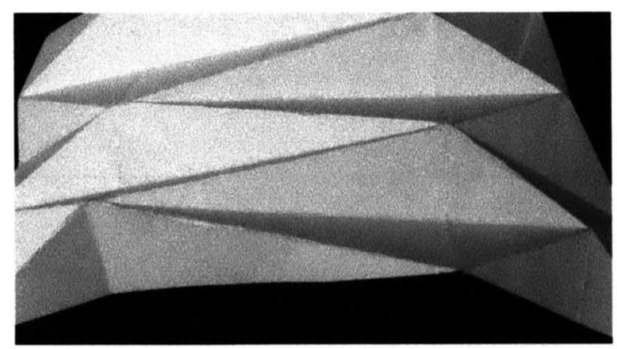
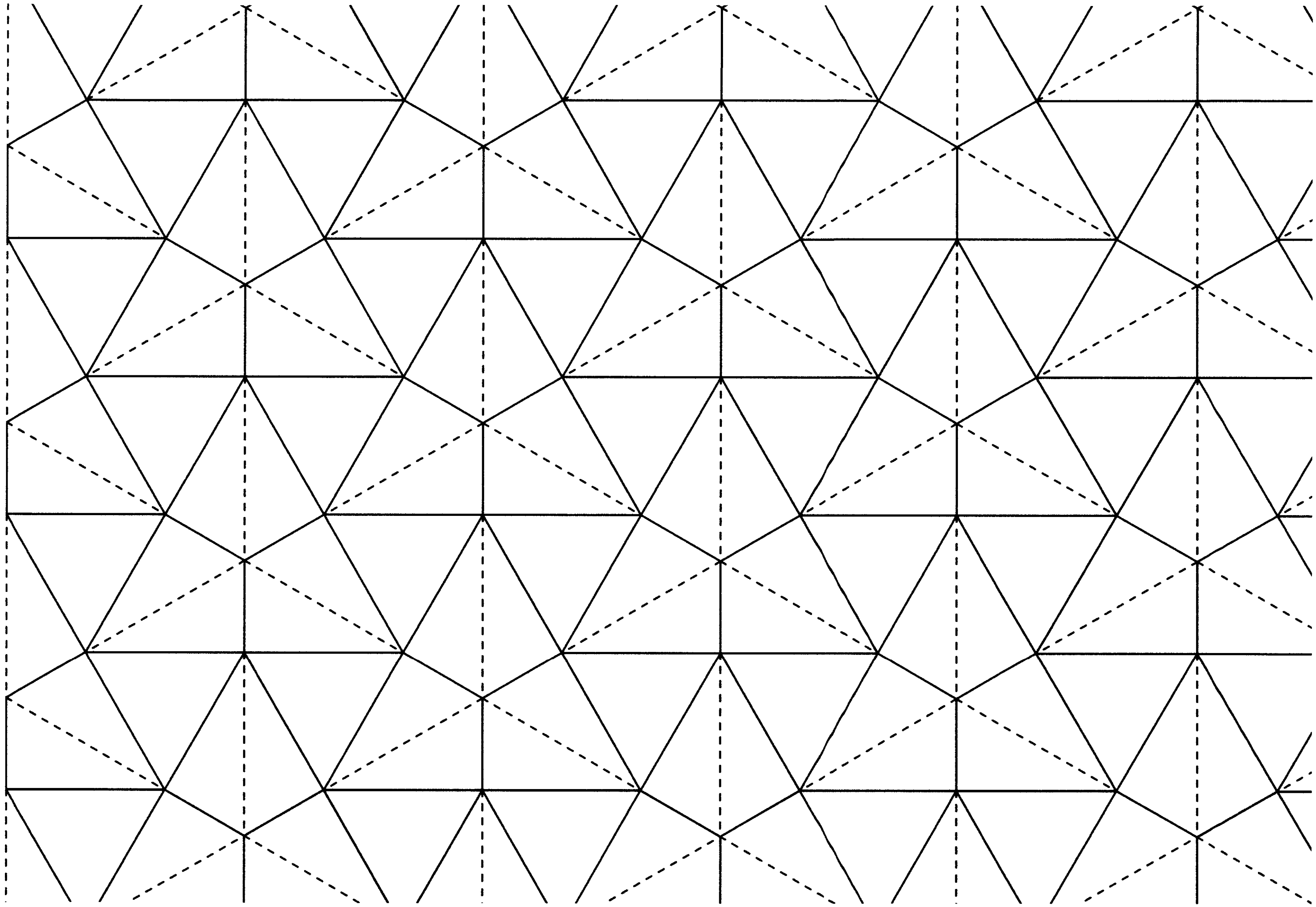


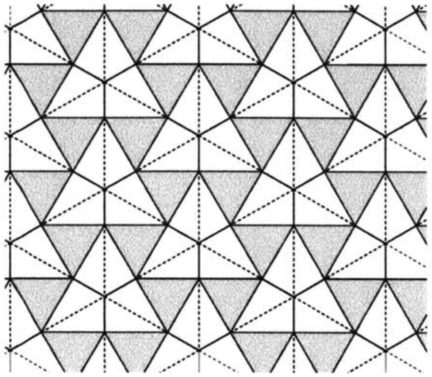


folded surface area: material thickness x number of ribs



PROTRUDED FOLD

EQUILATERAL TRIANGLES



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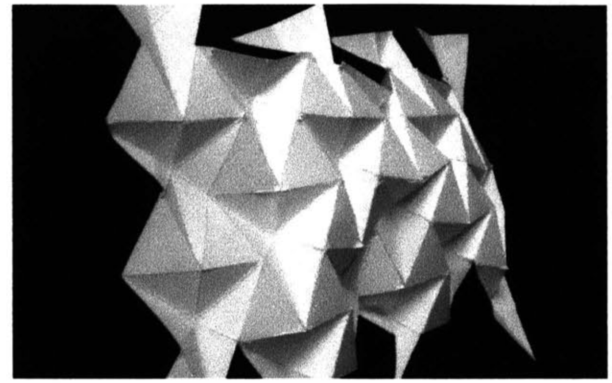

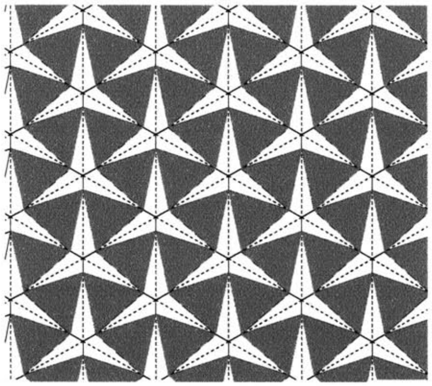

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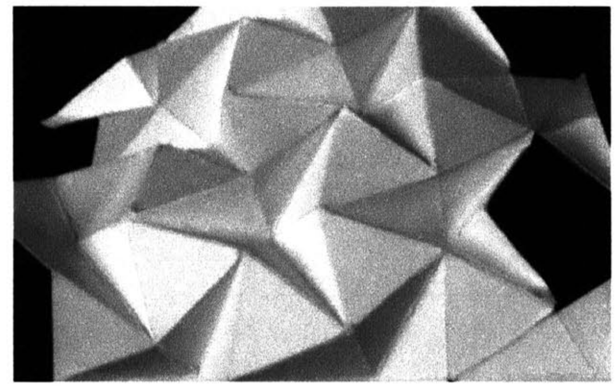
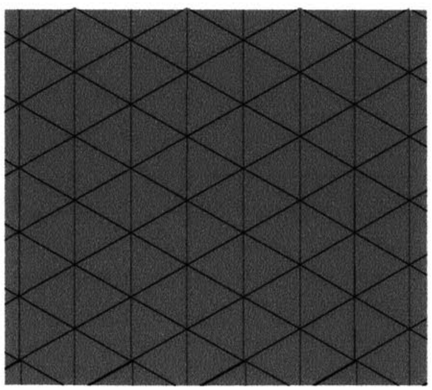
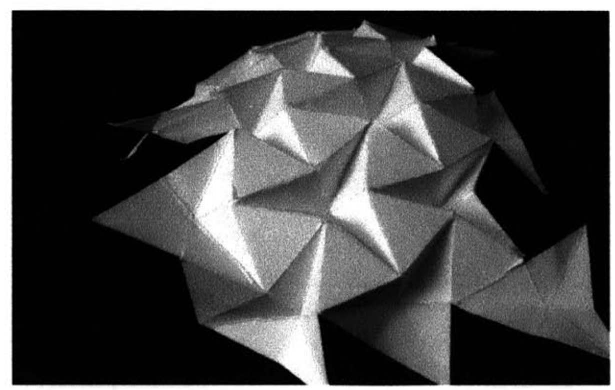
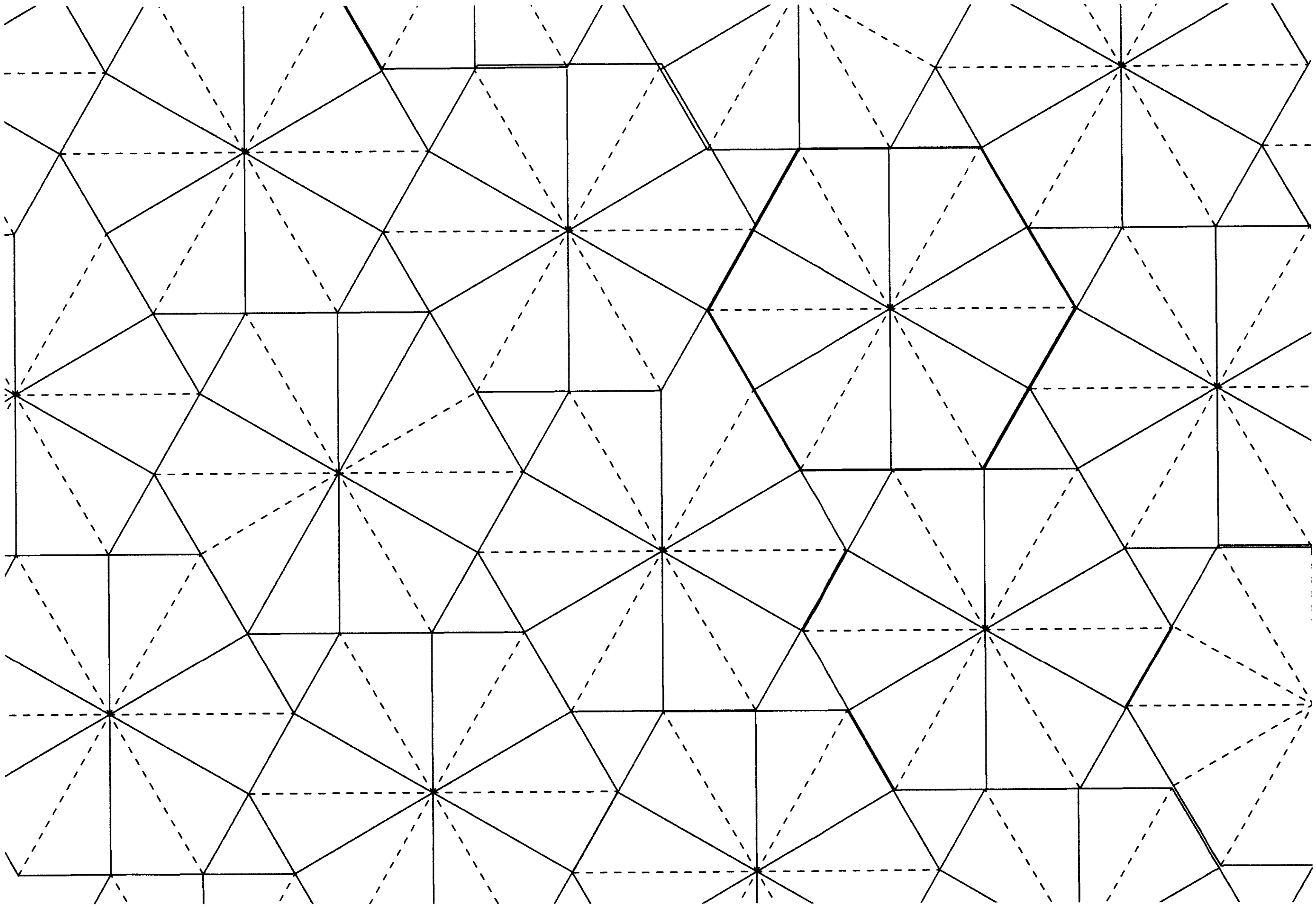
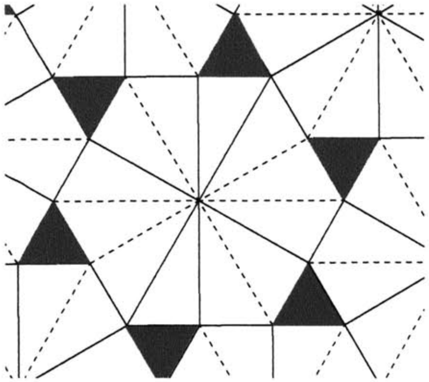




folded surface area: 22%







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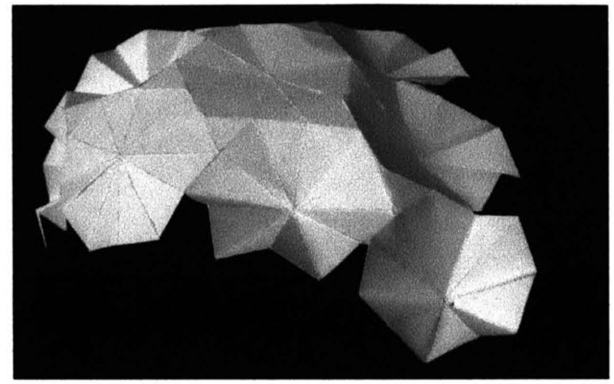

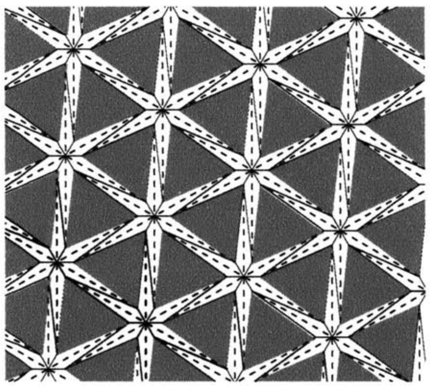

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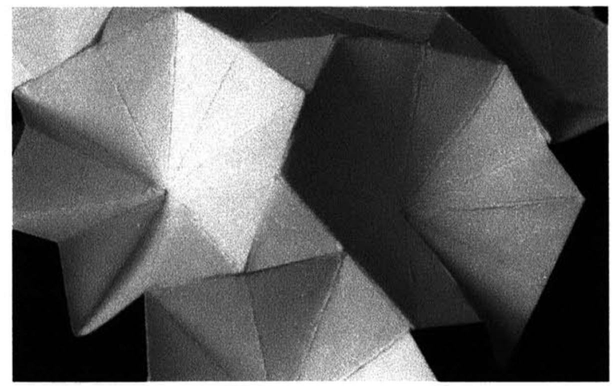
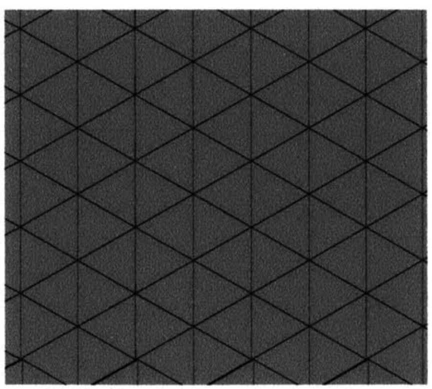
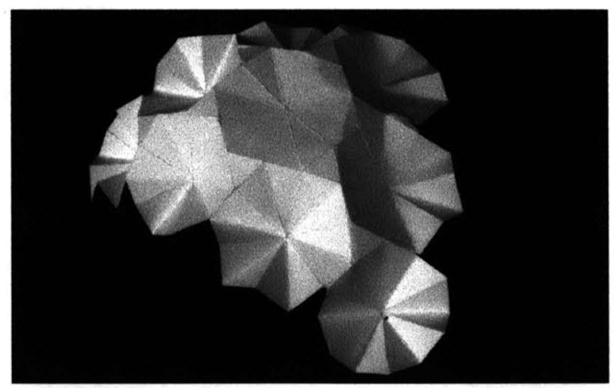
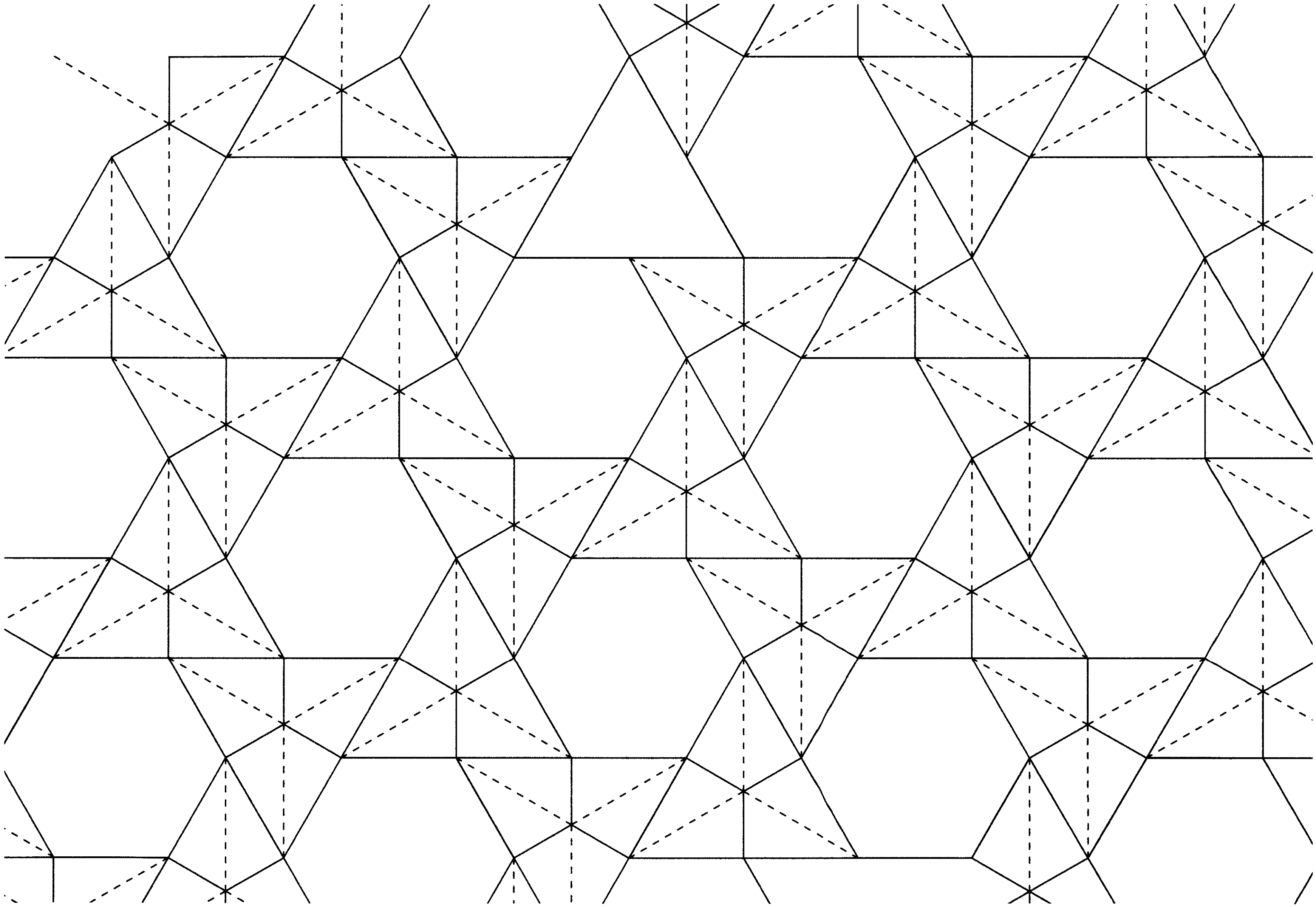
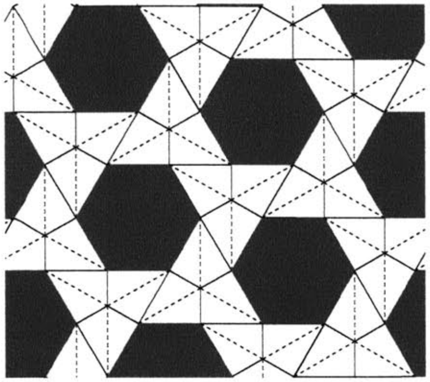




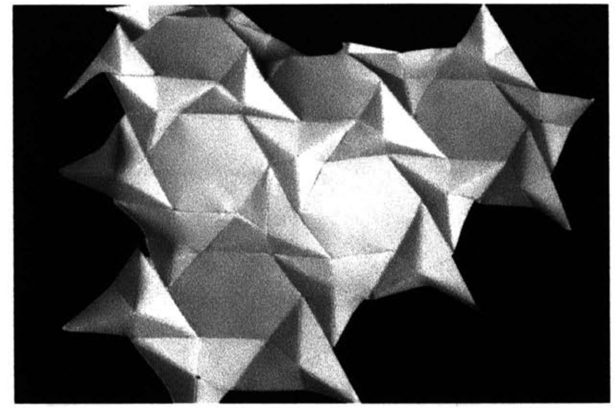
folded surface area: 3%

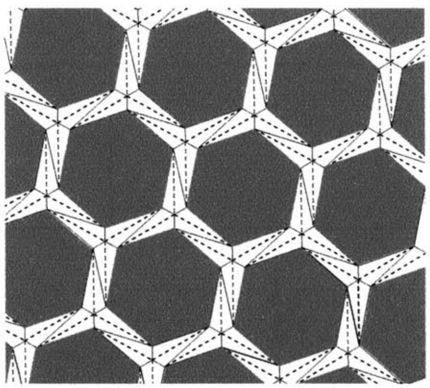




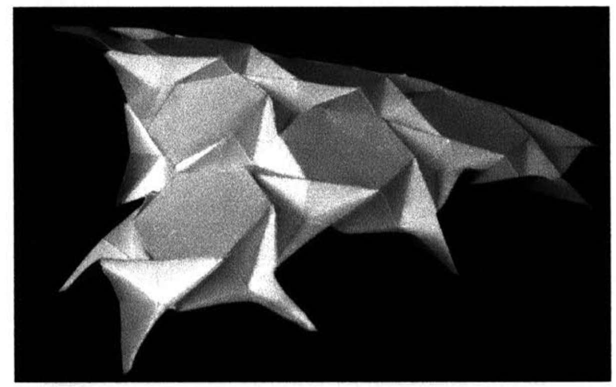


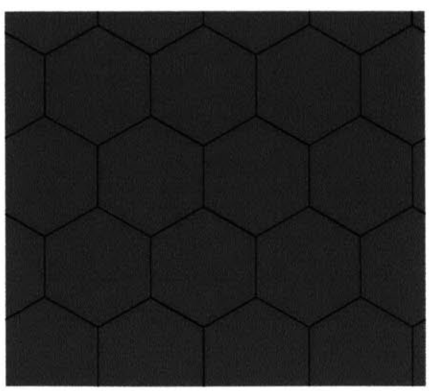
unfolded surface area: 100%



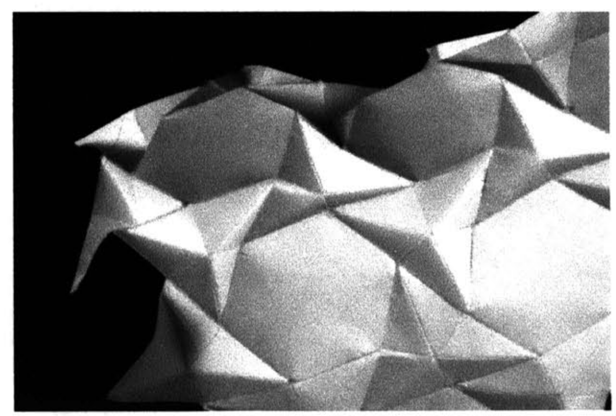


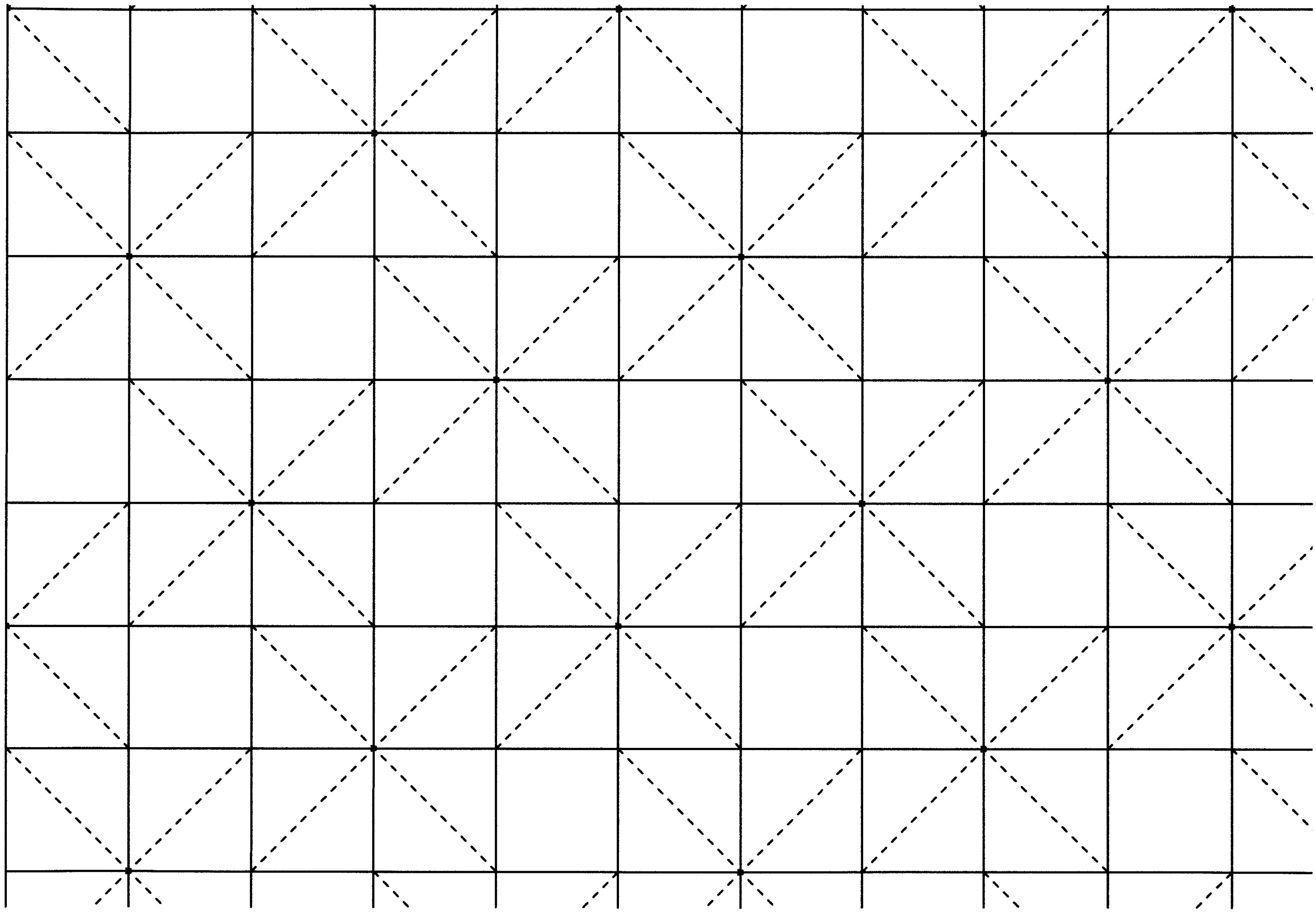
partially folded surface area: 50%





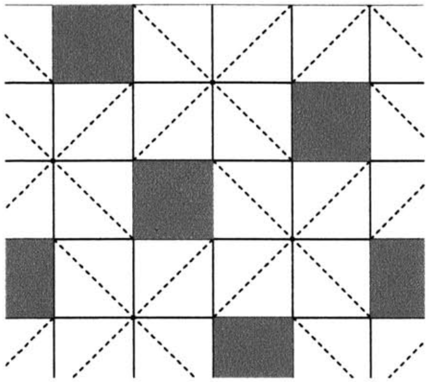
folded surface area: 30%

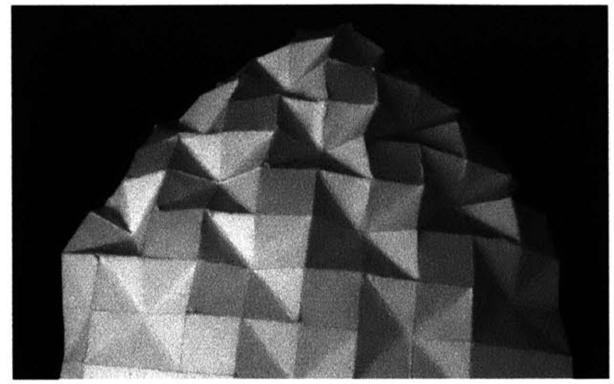




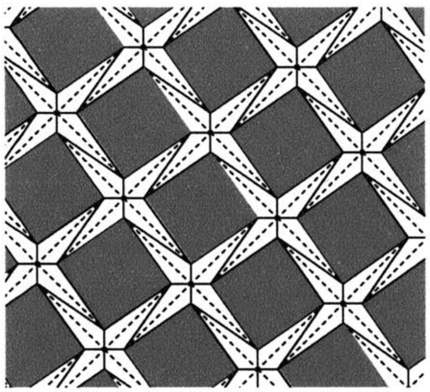
PROTRUDED FOLD

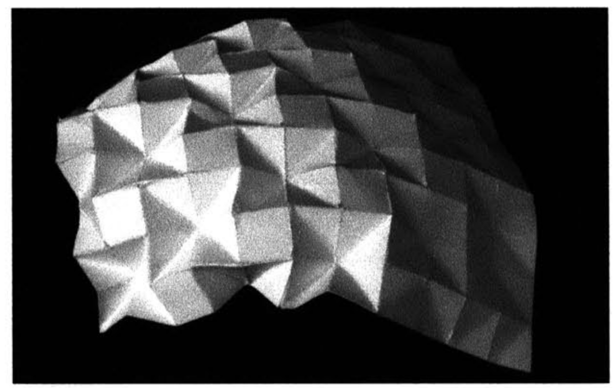
SQUARE



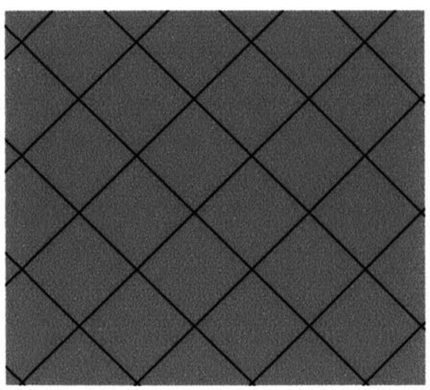


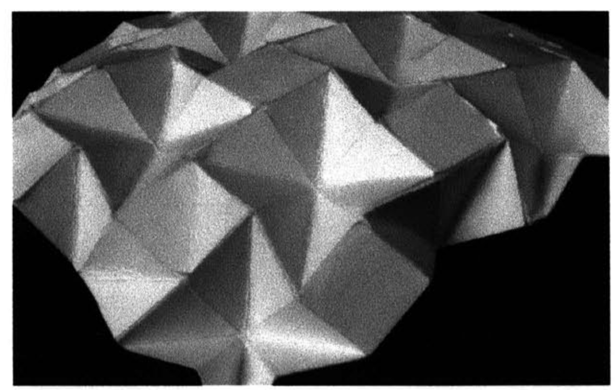
unfolded surface area: 100%



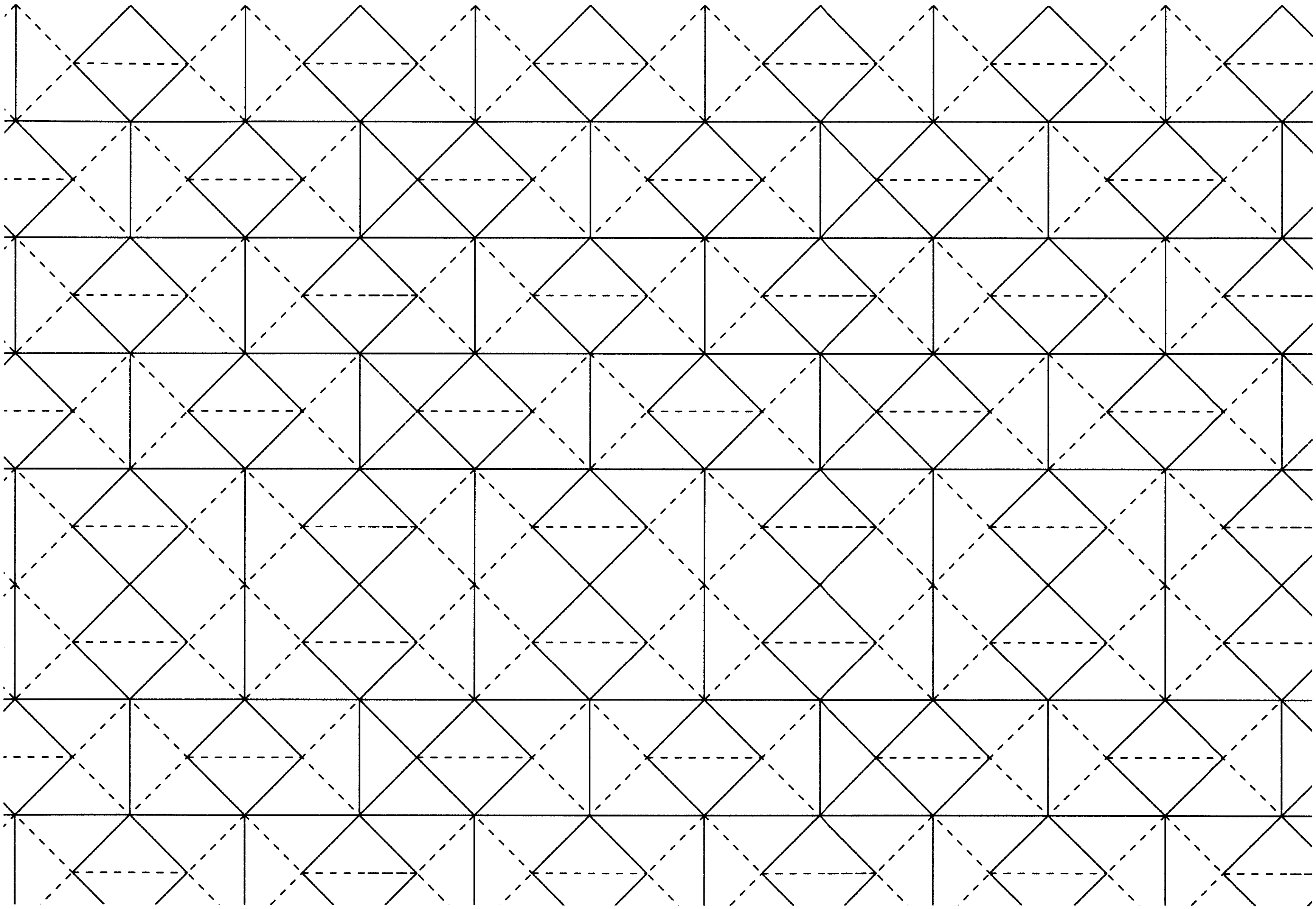


partially folded surface area: 50%

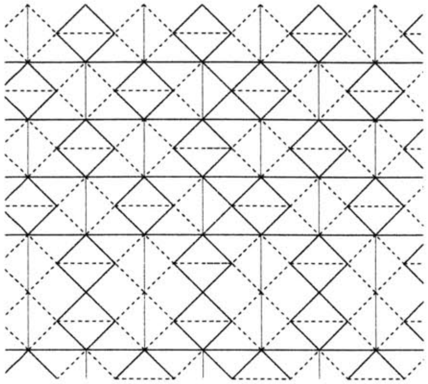




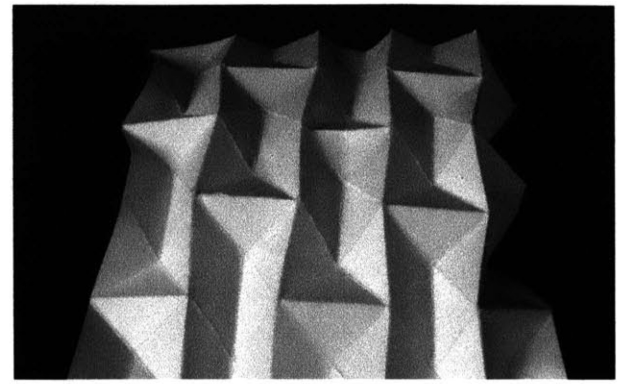
folded surface area: 18%

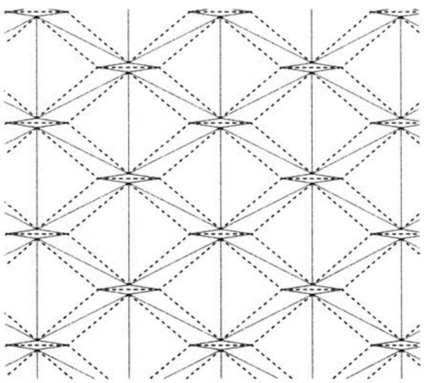


HYBRID FOLD

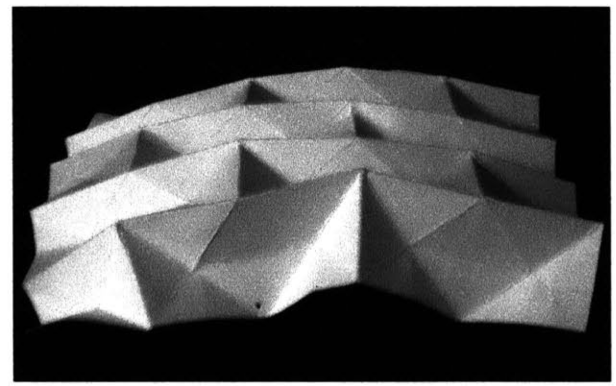


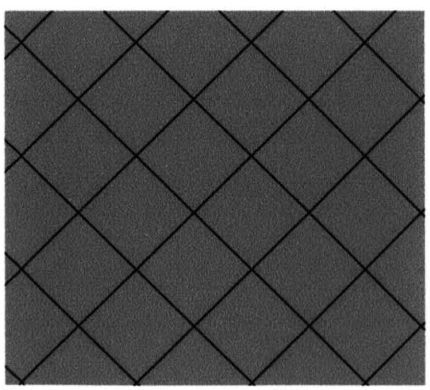
unfolded surface area: 100%



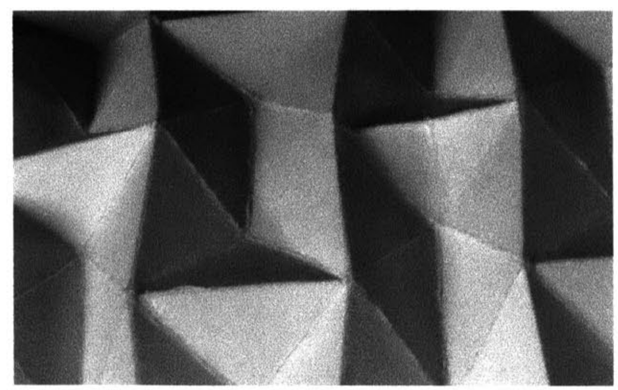


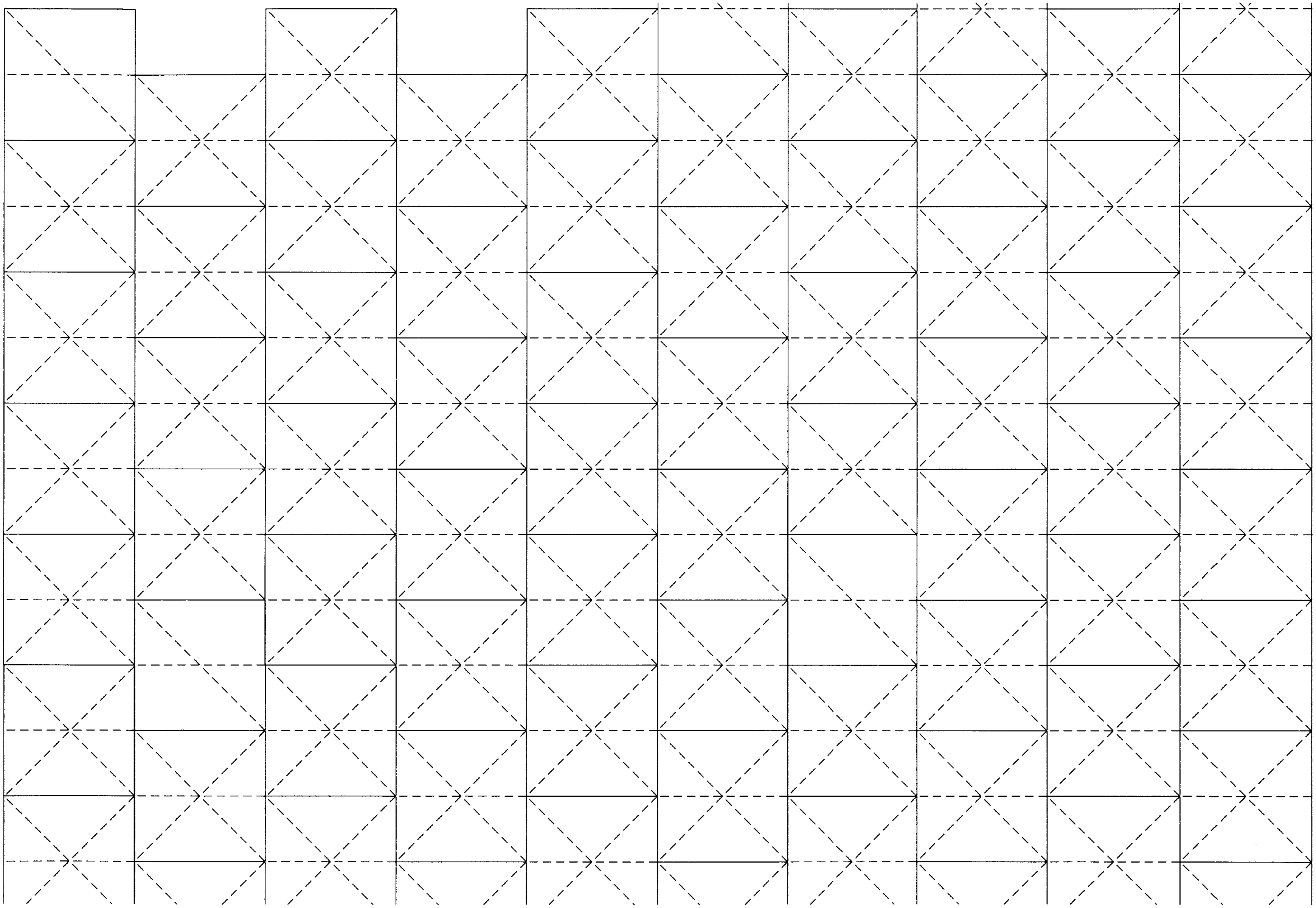
partially folded surface area: 50%



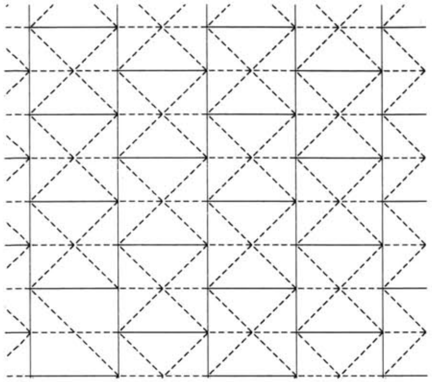


folded surface area: 45%

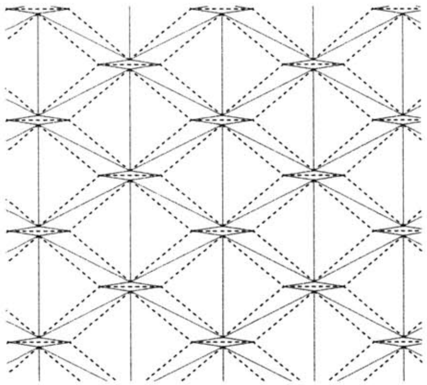




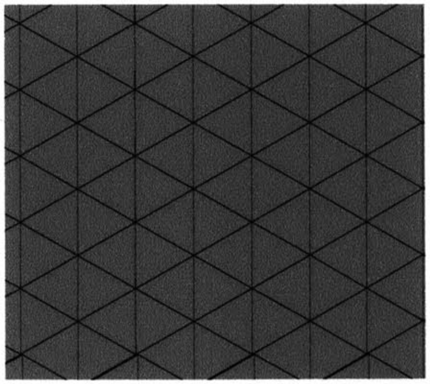
HYBRID FOLD



unfolded surface area: 100%



partially folded surface area: 60%



folded surface area: 50%

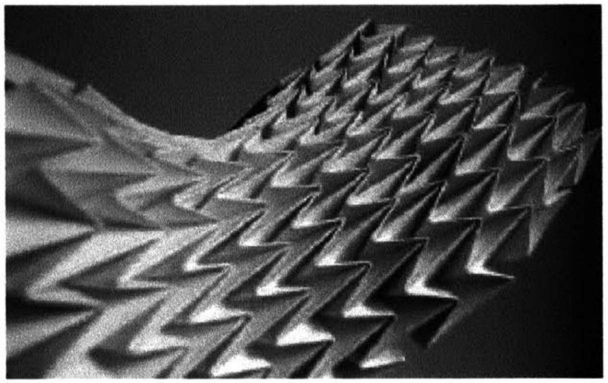


fig. 1

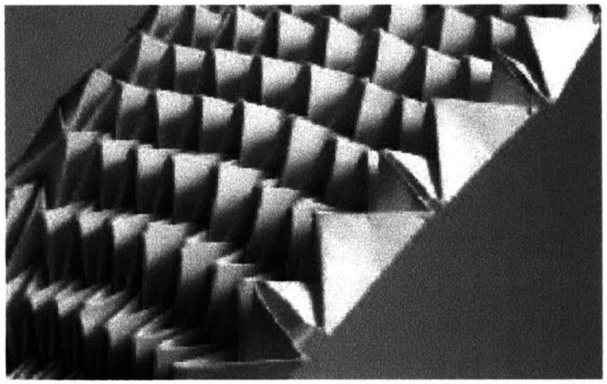
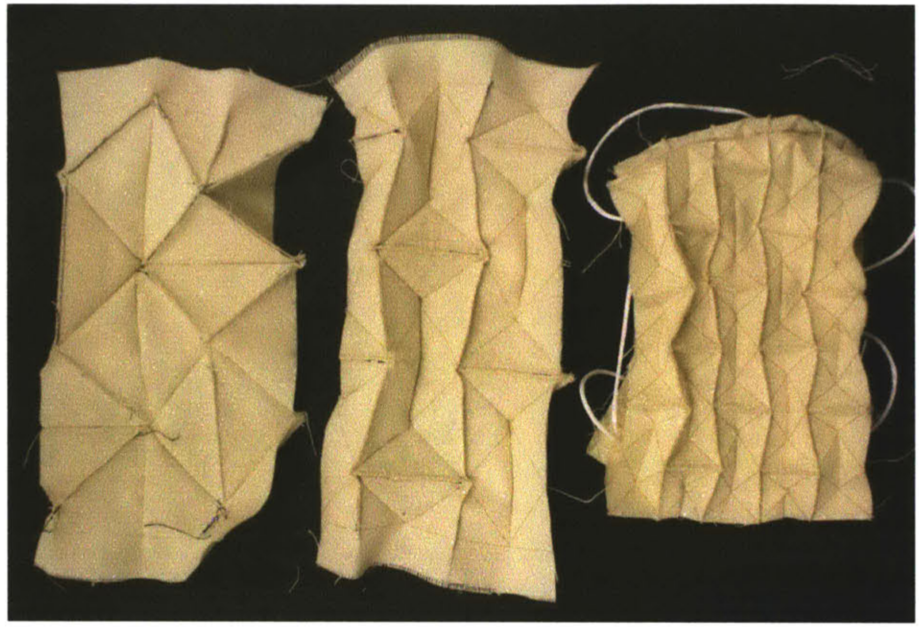


fig. 2

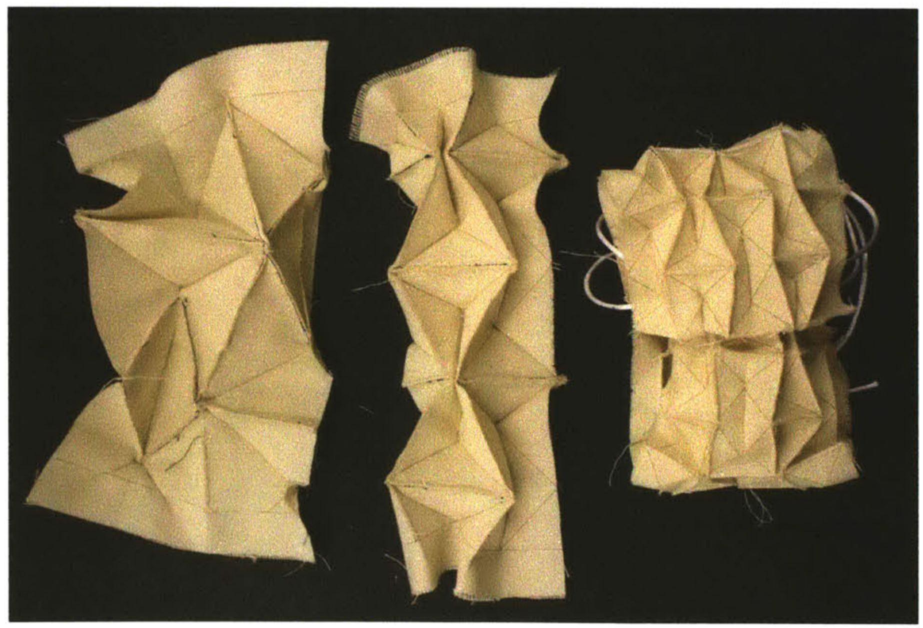
PATTERN MANIPULATIONS

SCALE MANIPULATION

This series explores the effects of different scales of a hybrid pattern applied to surfaces of the same dimensions. As the scale of the pattern increases, it begins to act as a volume rather than a surface pattern when folded.



folded

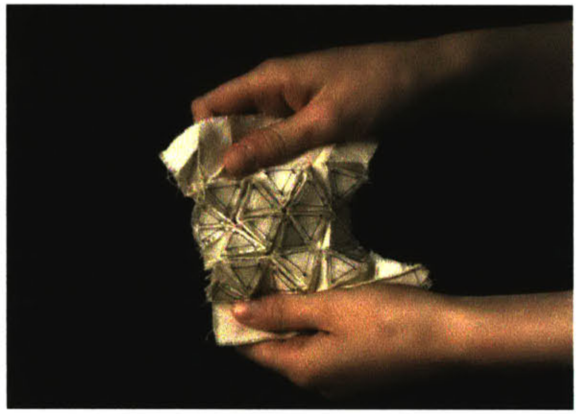


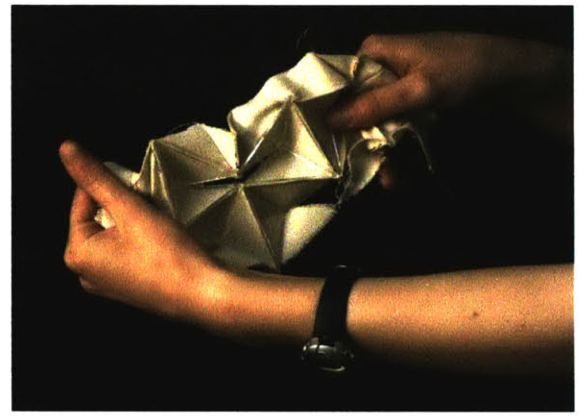
unfolded

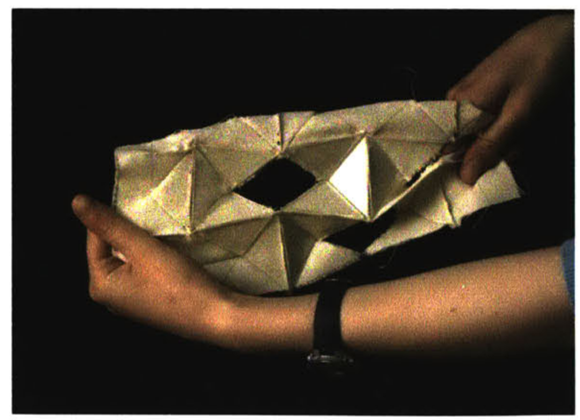
HARD / SOFT

A hard plexi surface is applied to the 'outer' surface of a protruded pattern (left) and a hybrid pattern (right) such that only the plexi is exposed when the pattern is fully folded. The hard panel surface suggests a sheltered canopy, protective facade or inhabitable surface, while the soft inner surface suggests something porous. In the hybrid pattern test, on the right, the soft surface is removed entirely and can become an operable aperture for daylight or ventilation.

unfolded and folded protruded pattern



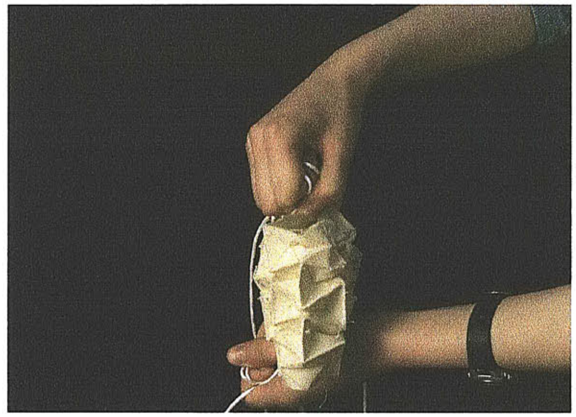




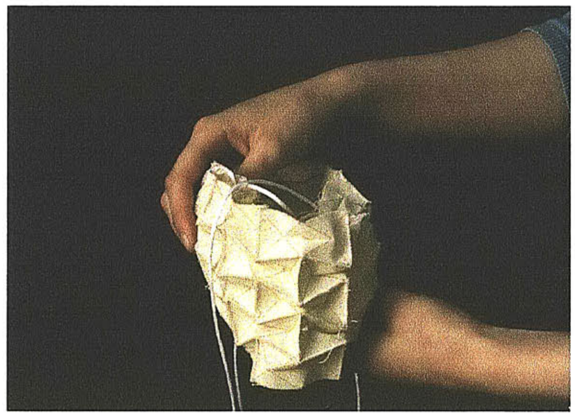
unfolded and folded hybrid pattern

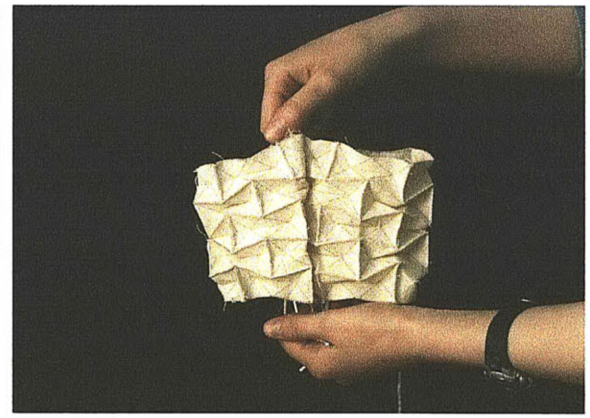
CINCHING

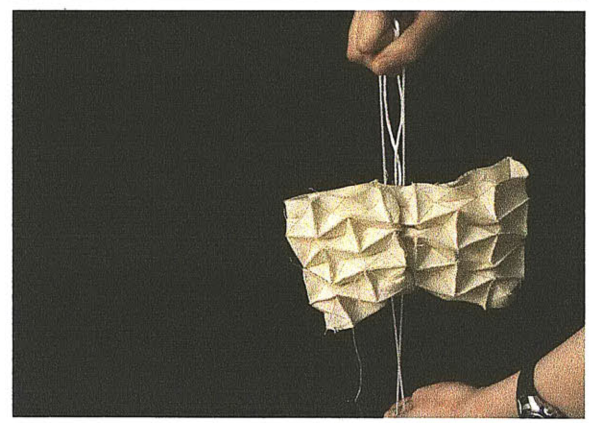
This series explores how a surface can be folded and unfolded via a cinching mechanism. The hybrid pattern is applied to a cylindrical surface. The surface can be folded by pulling strings at two ends which forces the surface to bunch. Due the creases, the bunching takes on the geometric pattern. A detail of this particular cinching method not illustrated here is the change of the inner space from one large volume when uncinched and two smaller volumes when cinched.



side view



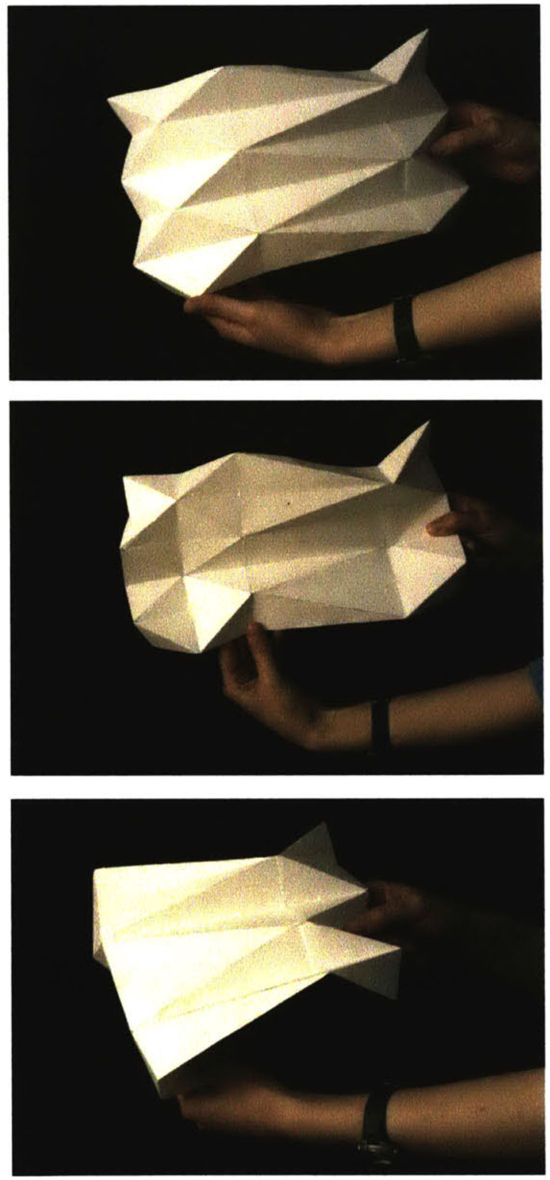




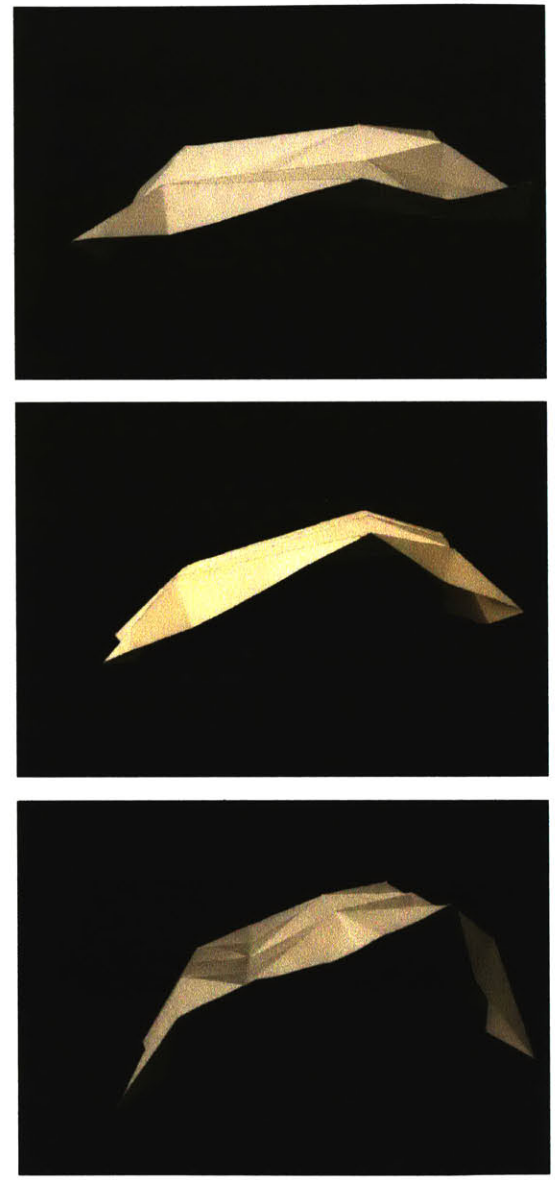
front view

POP IN / POP OUT

This exploration looks at the adjustments to the sectional properties of the diamond fold. By a changing a valley fold to a mountain fold, or by applying a horizontal fold instead of a valley fold, the volume has an entirely different spatial quality.



plan



elevation

ANALYSIS

	PATTERN VARIATION	GROWTH	SURFACE
PROTRUDED PATTERNS	heavily dependant on symmetry	only multidirectional growth	uniform outer surface when fully folded (no valleys and peaks)
ACCORDION PATTERNS	not symmetry dependant	potential for variation both linear and multidirectional	only ribs are revealed when folded, no 'outer surface'
HYBRID PATTERNS	somewhat dependant on symmetry	multidirectional expansion	outer surface with peaks and valleys when folded

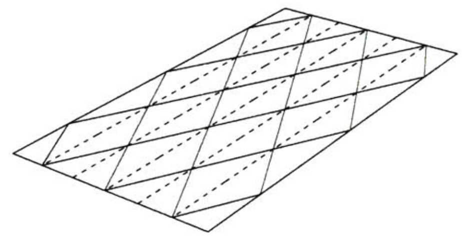
MUIRA ORI PATTERN and DIAMOND PATTERN
Both patterns are based on folded parallelograms. The nature of the diamond fold is more 'architectural' because the folded surface forms a curvature that can be read as a vault space or a c shaped enclosure. The thesis explores the possibilities and variations in manipulating and deploying forms created by the diamond pattern using the pop in/pop out method.

DIAMOND PATTERN BEHAVIORS

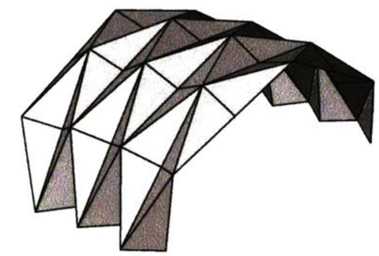
The diamond fold is characterized by straight valley fold (ribs) and diagonal mountain folds.

A characteristic of the diamond pattern is its ability to vary between a solid surface and a single strip surface. A strip occurs when a solid surface is cut along the rib. The separation allows the strip to fold independently from the surface. Independent folding allows gaps to appear between the strips. These gaps can become apertures for visual connections, daylight, ventilation and circulation.

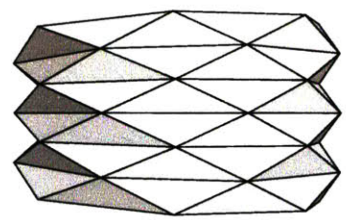
The solid surface behaviors allow the surface to fold without any gaps between different ribs. However this causes global curvatures along the surface which then need to be regularized in order to be placed on a flat site.



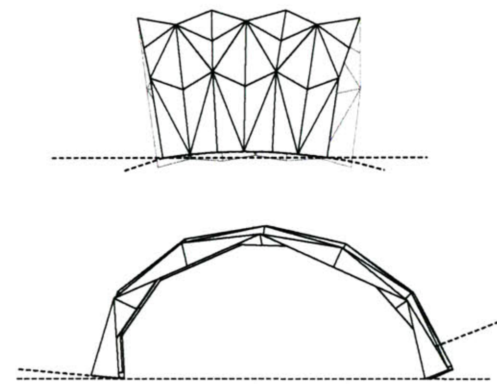
unfolded with crease lines



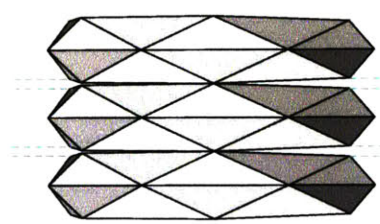
typical folded diamond pattern



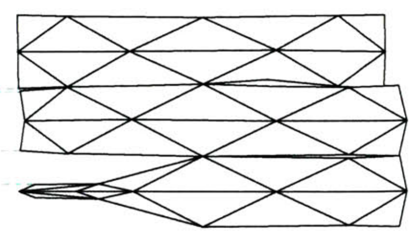
solid



global curvatures



strip



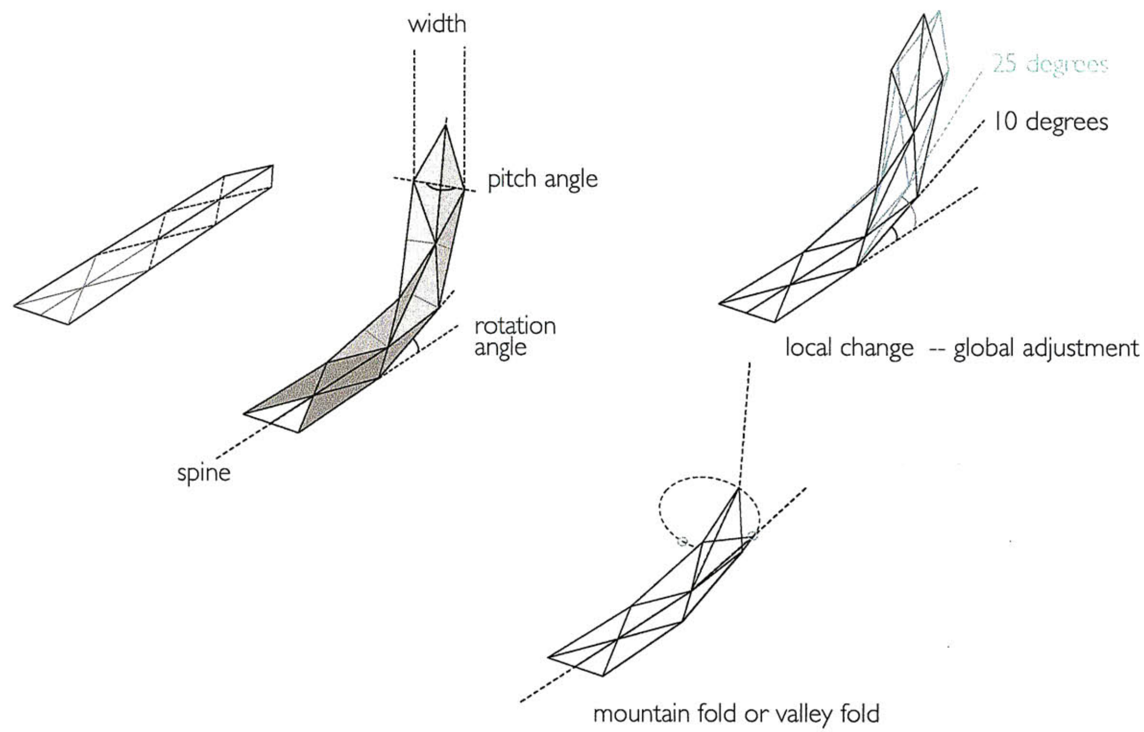
permeable, independent variation

FOLDING ANATOMY

The diamond pattern is analyzed by observing the behaviors of single strip. All parts of the anatomy of a strip (including the dimension of the diamond) can change and are interrelated.

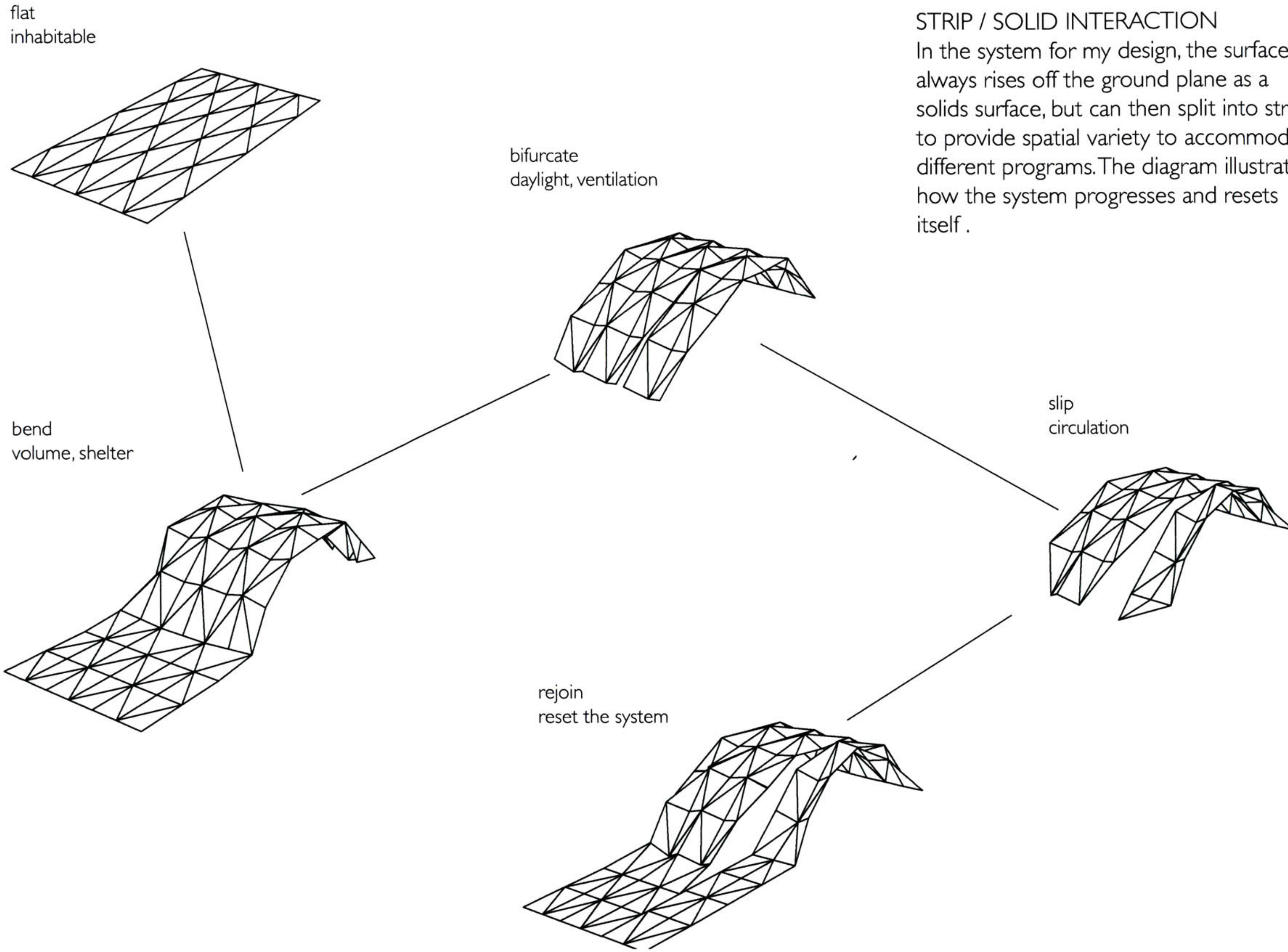
A few important characteristics to note:
- in order to go from flat to bent, the pattern must fold
- the greater the rotational angle, the smaller the pitch angle, the greater the depth of the strip.

The rules of a strip can be extrapolated to a solid surface. In the solid system, all the strips are aligned towards the global central spine rather than their individual spines.



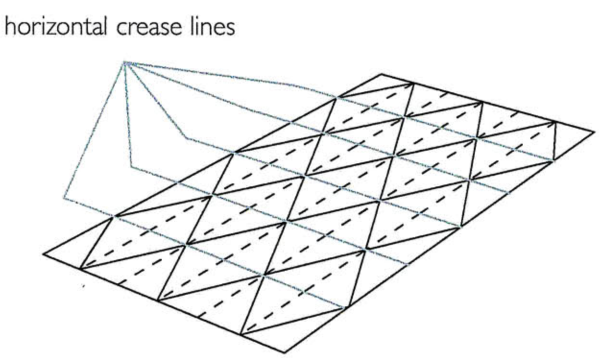
STRIP / SOLID INTERACTION

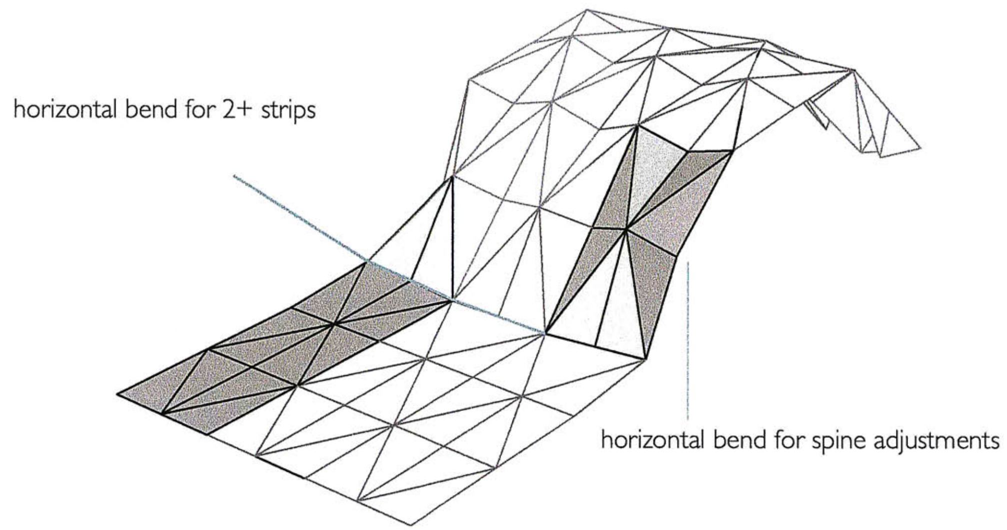
In the system for my design, the surface always rises off the ground plane as a solids surface, but can then split into strips to provide spatial variety to accommodate different programs. The diagram illustrates how the system progresses and resets itself .

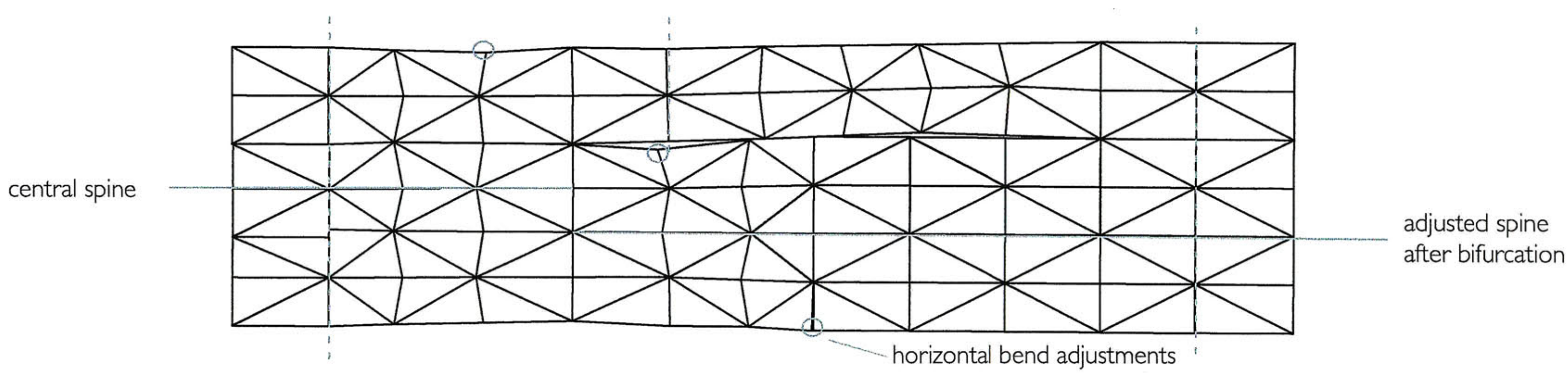


REGULARIZING

By applying horizontal creases to the system, the solid surface can fold while overcoming global curvatures as described previously. It also allows the strips to fit into a grid system which becomes important once it is applied onto the site.







DESIGN PROPOSAL

SITE

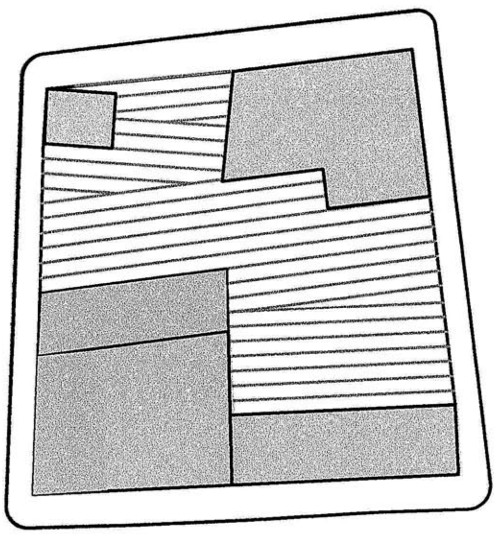
The site is located in Bronx, New York where there is a burgeoning street style fashion movement. Located off Fordham Road, the site is located along a stretch of ground floor commercial and retail stores. The pavilion can be used as a market during the weekends and weekday nights, but also serves as a semi-covered park during other times. The pavilion takes over a parking lot that connects two streets, Webster Avenue and Park Avenue.

Site: Bronx, New York
Current Use: Parking Lot
Square Footage: 20, 000sf

GRAIN

The site is divided into 8' strips that align to the angles of the site. Some parts of the grain 'thicken' to become solid surface which provide coverage for a larger spaces.

The site plan on the right shows the parts of the design where the geometric form serves as canopy and as flat inhabitable 'runways'.



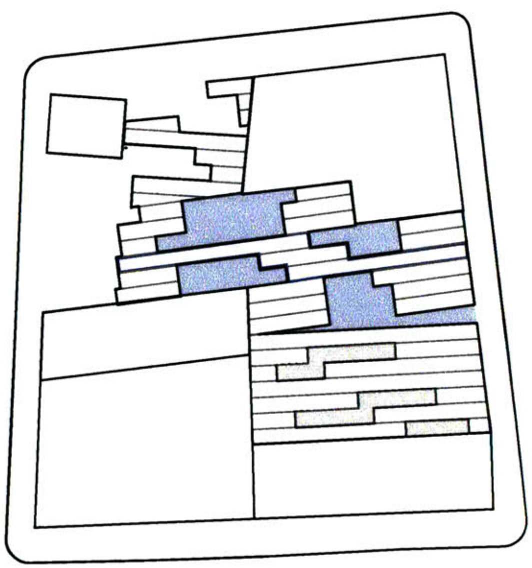
8' grain alignment to site

plan through canopied spaces

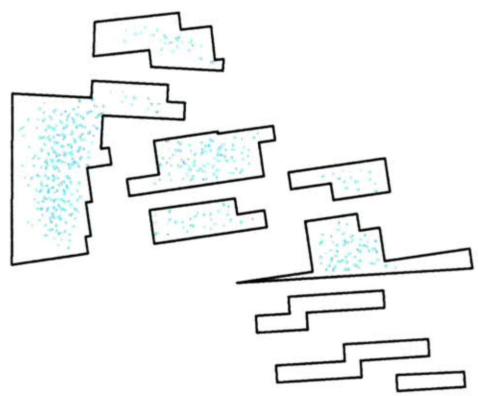
north

CIRCULATION

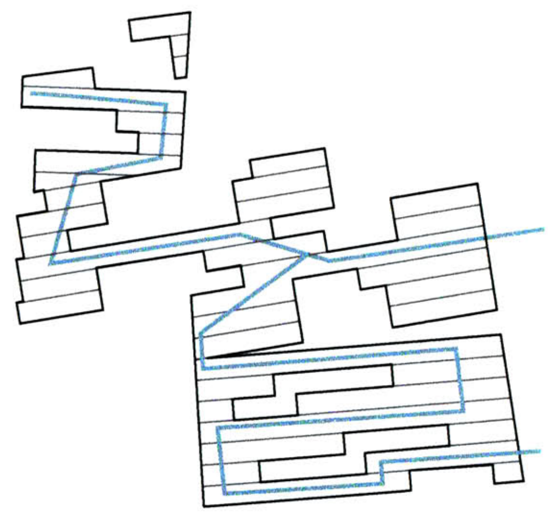
The canopied zones serve as the space for the bulk of the program. The open zones provide space for a meandering flow. The zones are connected by the the flat 'runways' which serve as circulation. The circulation paths can also be closed off in sections to serve as a formal runway with canopied audience seating areas along the sides.



program zones



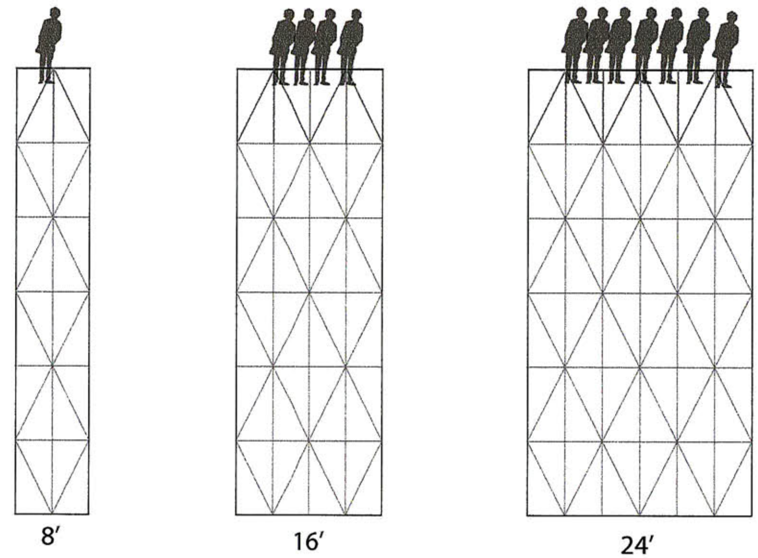
swarm circulation canopied zones



'runway' circulation

GRAIN AND PROGRAM

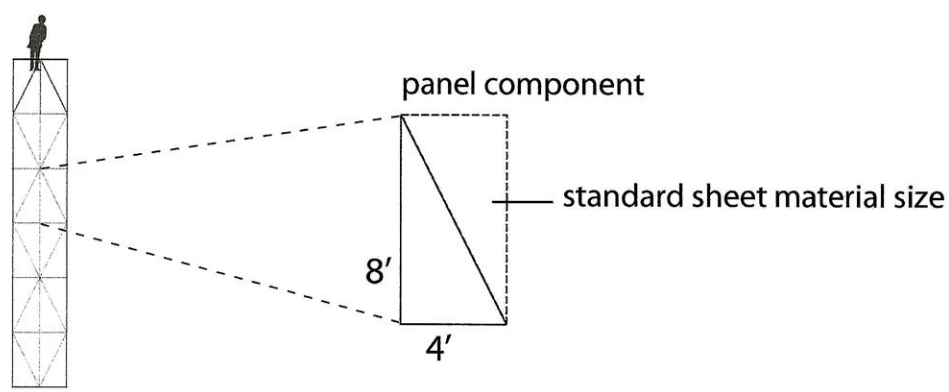
The thickening of the grain can happens in multiples of 8 feet wide strips and can accommodate different programs which have varying capacity demands



retail	fitting rooms	clothing display	indoor event seating
workshop		workshop space	workshop space
runway	runway	runway seating	runway seating
park	park bench		outdoor movie seating

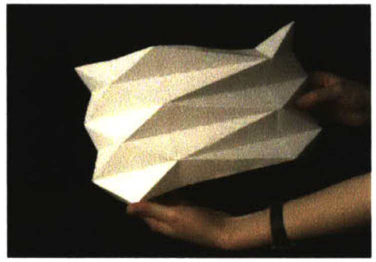
PANELING

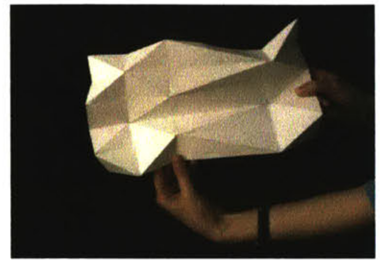
The regularity in the dimensions of the strip allow the same size panel to be used throughout the entire design. All panels are 4'x 8', exactly half of the standard sheet material size.



FOLD ABNORMALITIES

By using the pop in / pop out manipulation, a mountain fold can change to a valley fold, creating a new spatial quality. In the design, the manipulation is applied to three specific programs that require differentiation from the standard diamond fold space.

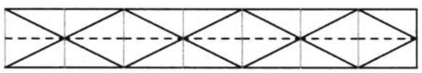


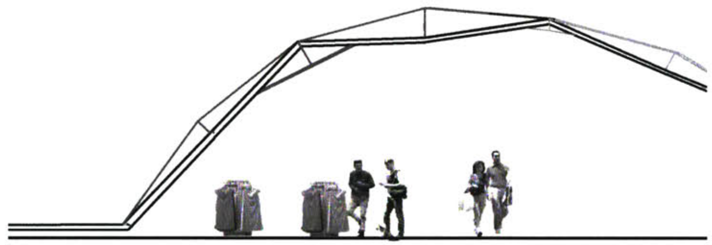


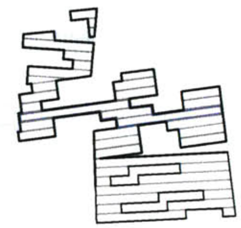
fold pattern | section | location on site

typical market and event seating

standard diamond fold

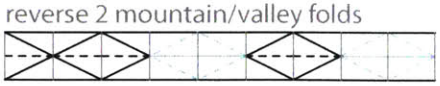


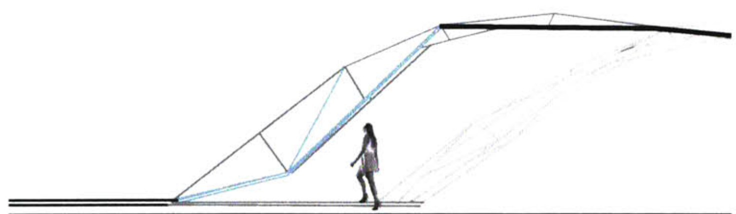


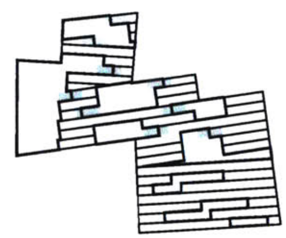


indoor/outdoor transition

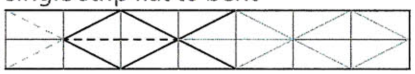
reverse 2 mountain/valley folds

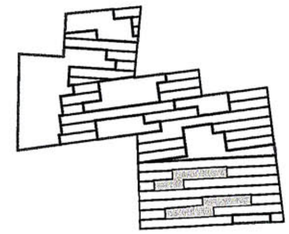




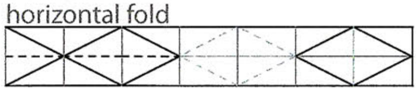


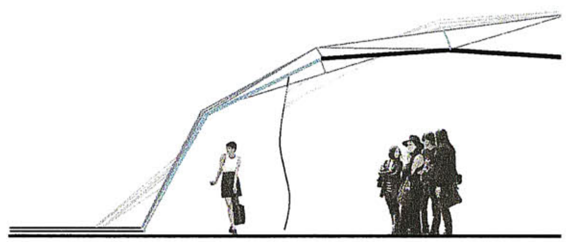
bench
single strip flat to bent

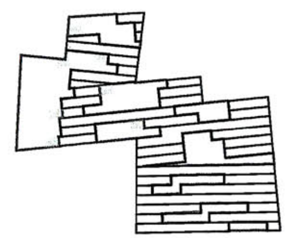




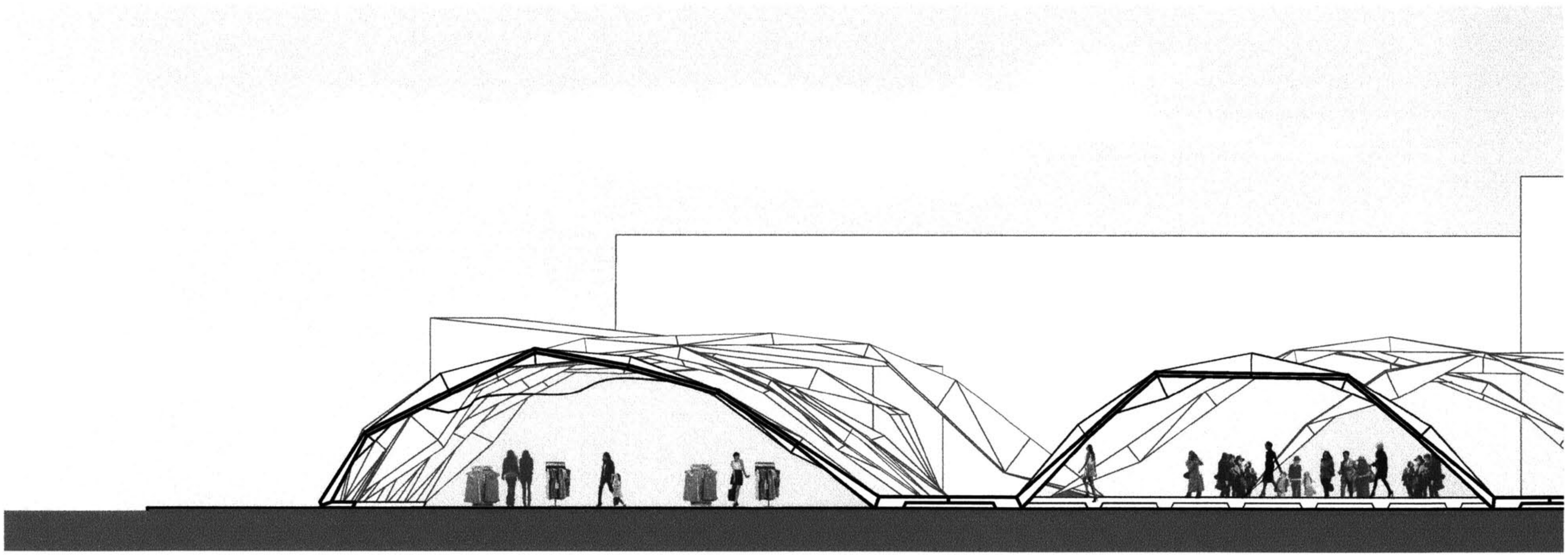
fitting room
horizontal fold

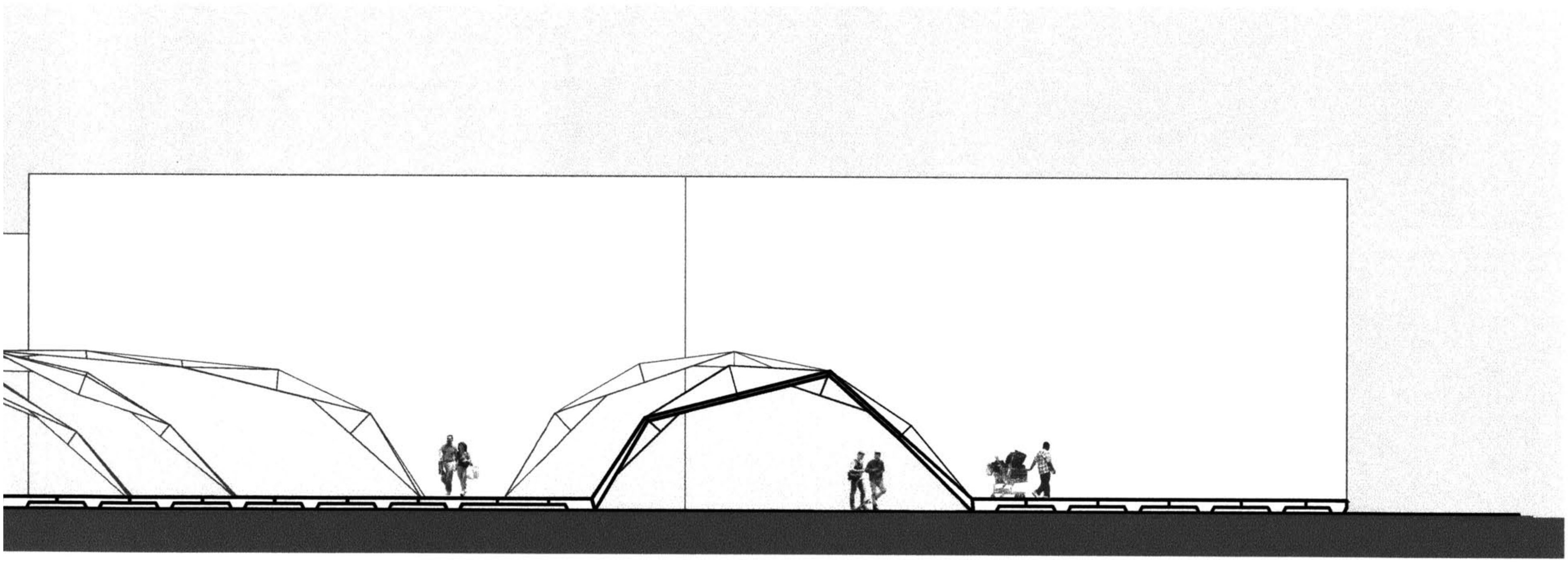


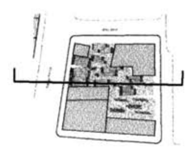




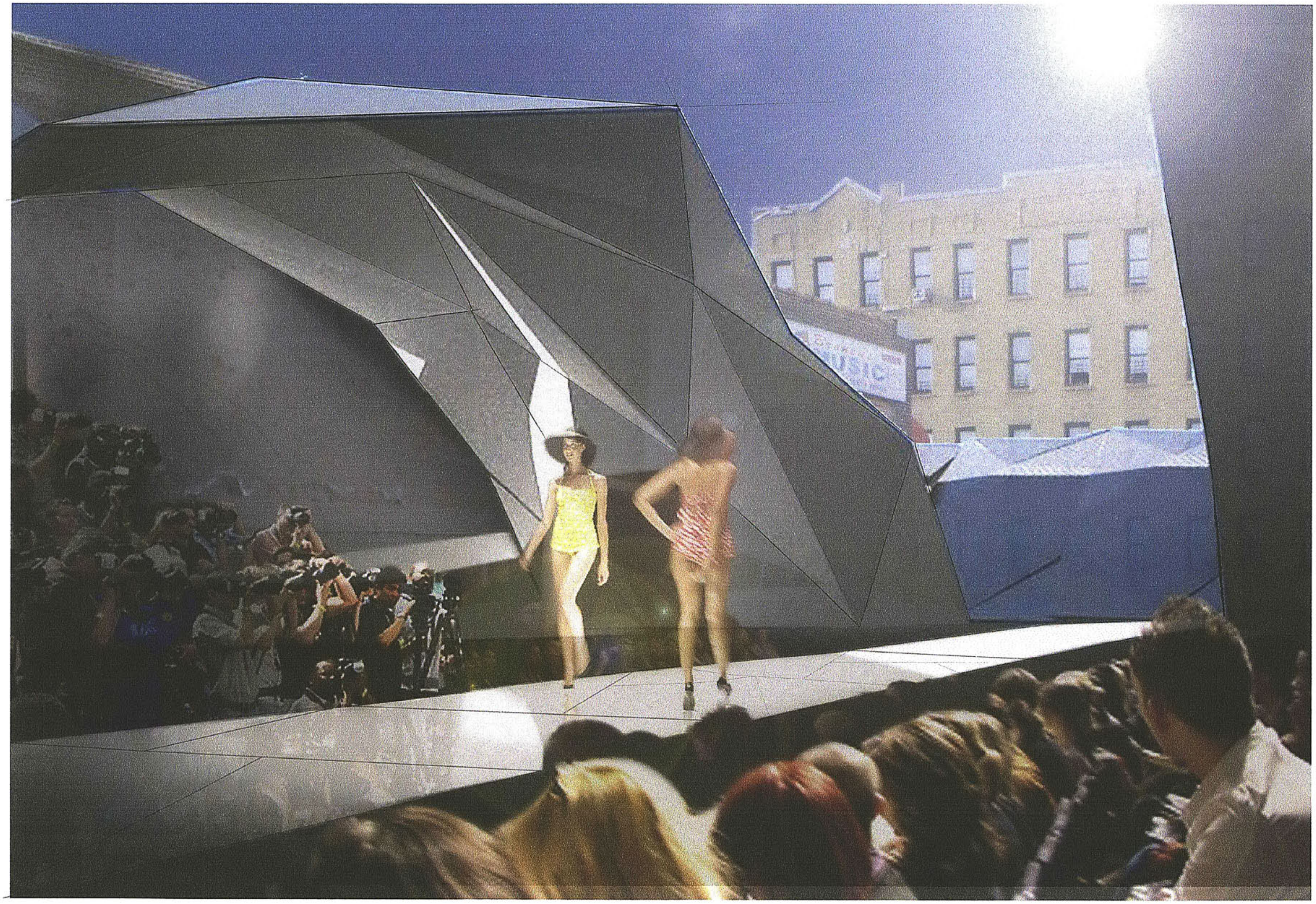
RENDERINGS AND MODELS



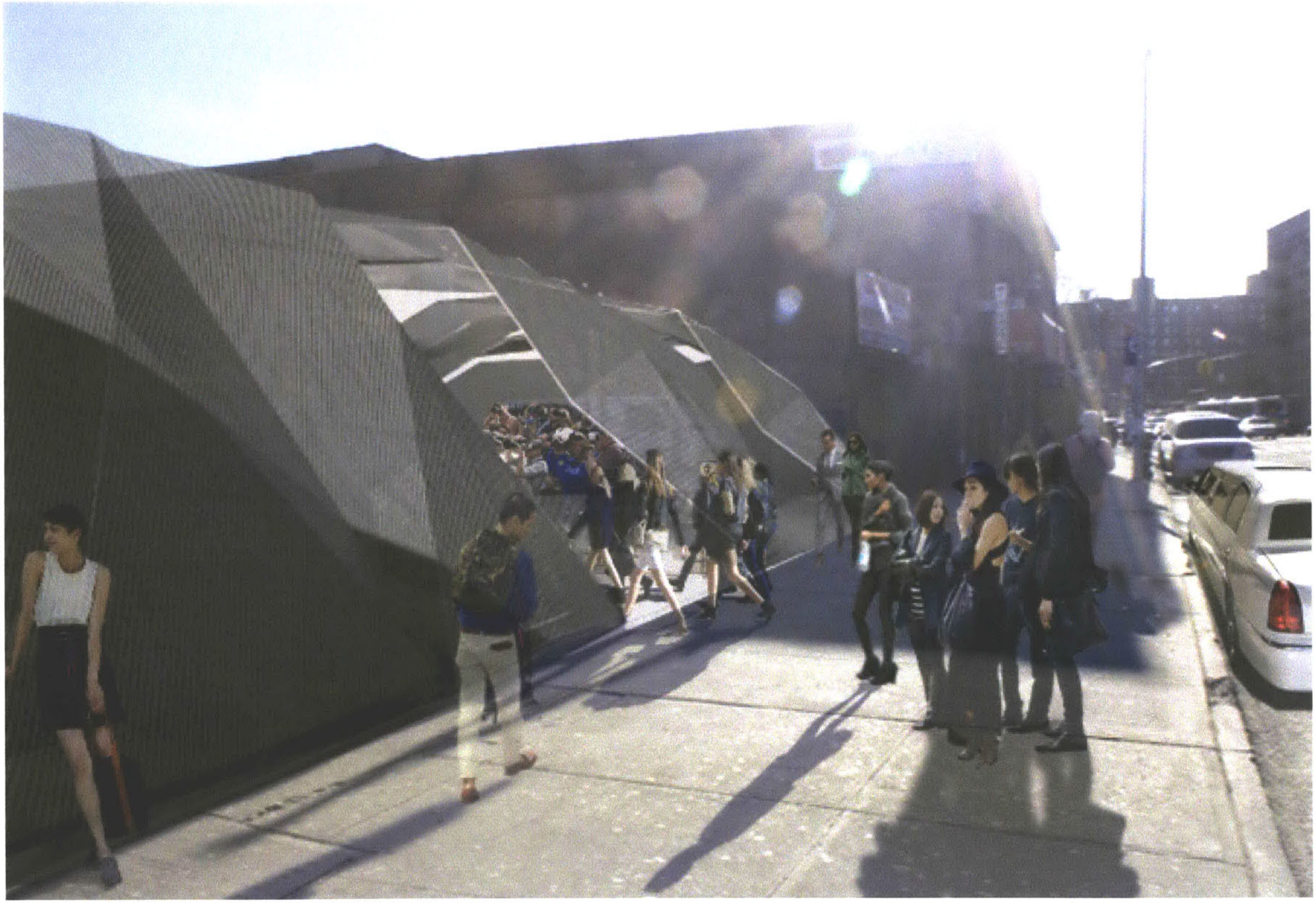




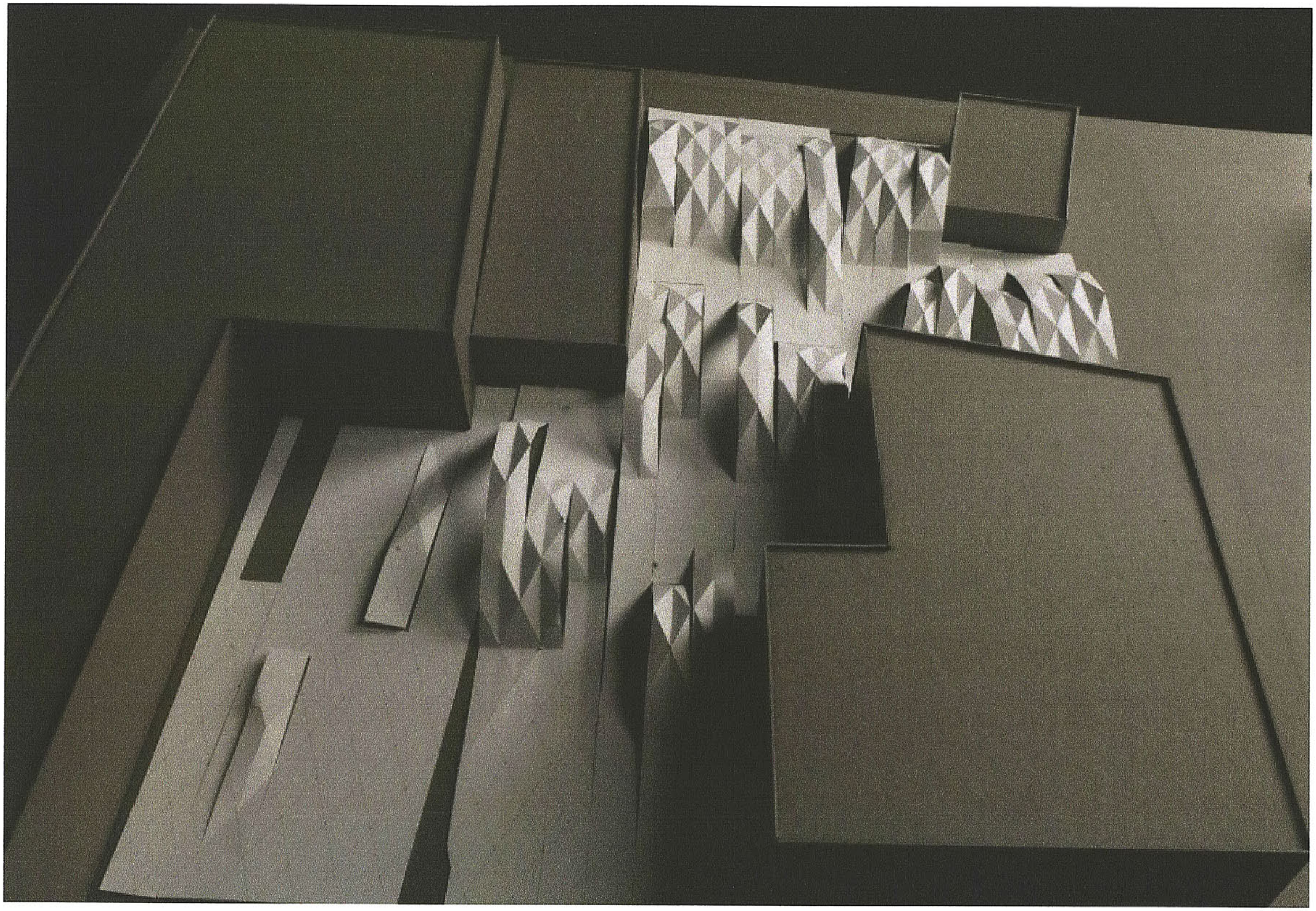
SECTION THROUGH CENTRAL RUNWAY



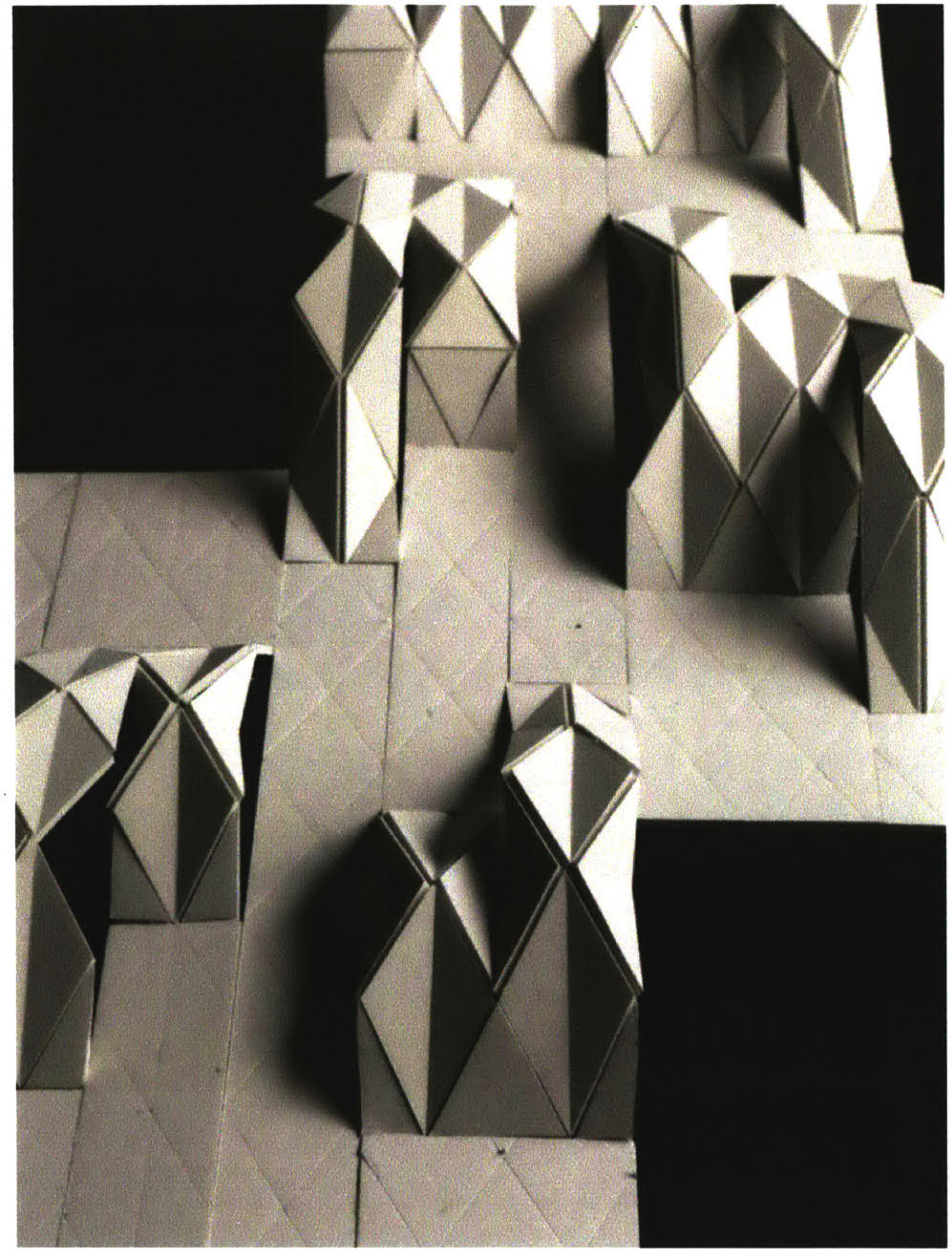
RUNWAY EVENT



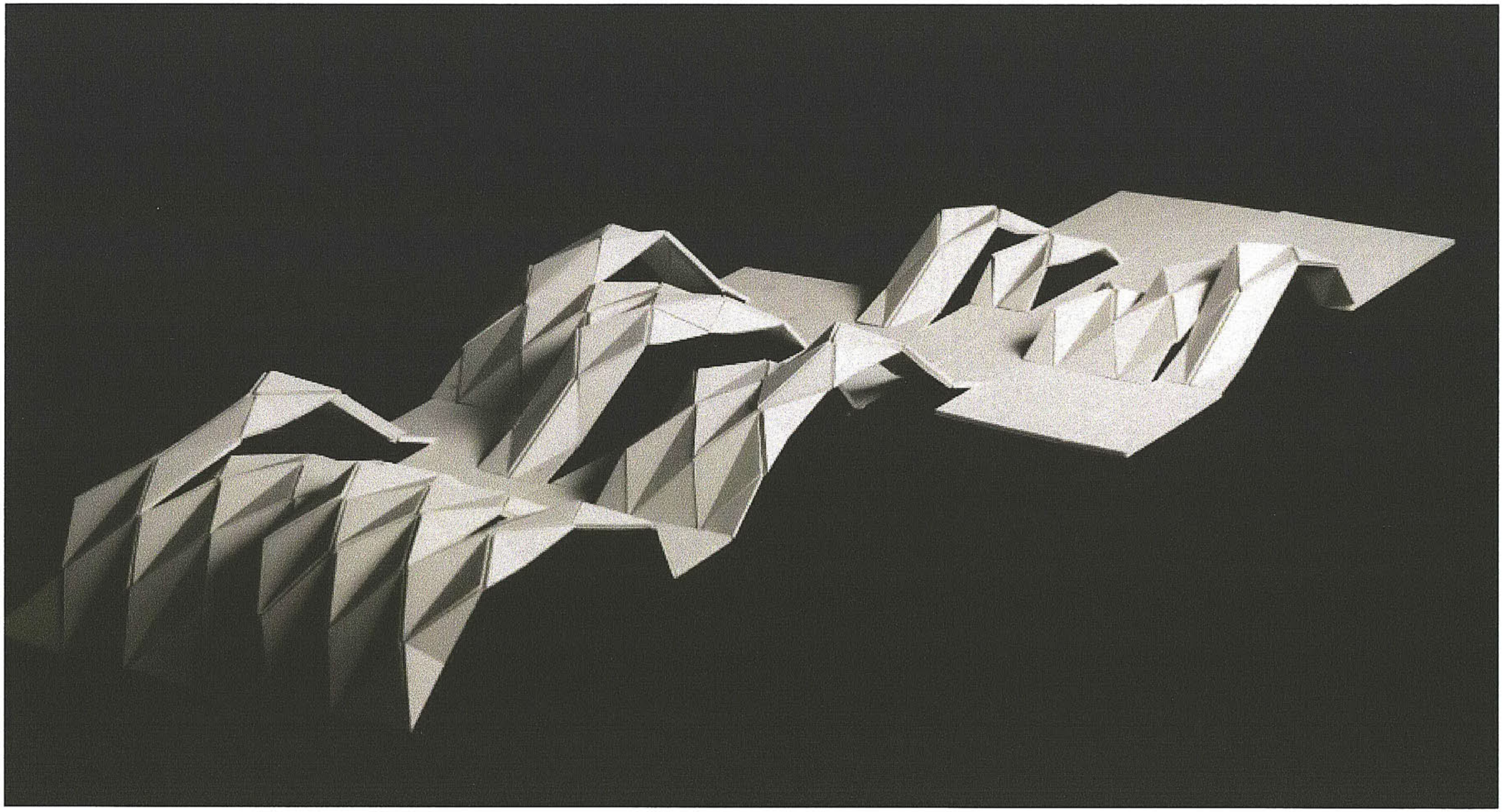
VIEW FROM WEBSTER AVENUE



MODEL AT 1/8 SCALE



MODEL AT 1/4 SCALE



MODEL AT 1/4 SCALE

APPENDIX
BIBLIOGRAPHY
IMAGE CREDITS

APPENDIX
FOLDING / GEOMETRY PRECEDENTS

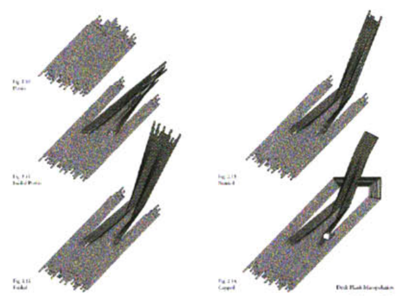


fig 3.

Liam O'Brien
Weathers Permitting (2010)
Materials: Wood

Employs geometric varations to create outdoor conditions


fig 4.

Office dA
Installation for MoMA (1998)
Materials: Folded sheet metal

Employs unique scoring technique for folding metal


fig 5.

Pier Luigi Nervi
Orvieto Aircraft Hangar
Materials: Concrete and brick

Diamond gridded structure allows for an extremely thin shell

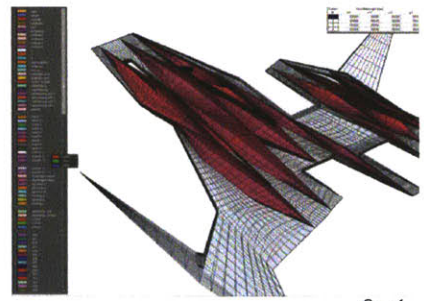


fig 6.

Tom Wiscombe
Light - Wing (2003)
Materials: Metal, Fabric, Light

Uses a light fabric over a metal geometric framework

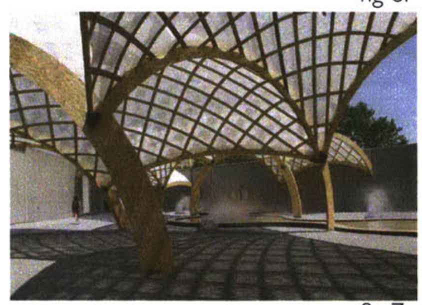


fig 7.

Obra
Beatfuse (2006)
Materials: Wood and fabric

Uses propelyene mesh pieces to cover structure

University of Cambridge
Cardboard Pavilion (2009)
Materials: Cardboard

Uses diamond pattern on cardobard to create pavilion structure.

FASHION PRECEDENTS


fig 9.

Work Architects
Target Pop Up Store (2003)

Free standing curtain dressing rooms throughout the store


fig 10.

OMA
Prada Epicenter New York
(2001)

Intergrates event space serves both as a circulation and retail display space


fig 11.

OMA
Prada Transformer Pavilion
(2009)

A rotating fashion pavilion adapts to four programmatic needs. Textile cladding with street frame.


fig 12.

Zaha Hadid
Chanel 2.55 Traveling Pavilion
(2008)

An art exhibition pavilion made out of fiberglass panel facade with a two year life span.


fig 13.

OMA
Prada Runway (2008)

Untraditional ramped runway winds through existing colonades to engage to the space.


fig 14.

Alexander McQueen Runway
(2008)

Uses fabrics decoration as well as walking surface.

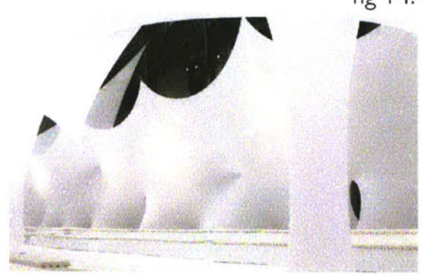


fig 15.

Yves Saint-Laurent Runway
(2008)

Hyperbolic tensile texitle surfaces used as enclosure for runway and seating within a larger hall.

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IMAGE CREDITS

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Fig 2. www.spacesymmetrystructure.wordpress.com

Fig. 3. Weather Permitting: A Field Guide to Transitional Environments by William O' Brien (2010)

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Fig. 14 www.wallpaper.com

Fig. 15 www. wallpaper.com